Levels of Essential and Toxic Metals in Milk and Baked Products

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Abstract

Seven essential metals (Ca, Cr, Cu, Fe, Ni, Se and Zn) and two toxic ones Cd and Pb) were determined in milk and some baked products (bread, meat pie and sausages) by atomic absorption spectrophotometry using air-acetylene flame. The mean concentrations (mg/kg, wet matter) were in the following ranges: Ca (29.12 – 7894.45); Zn (2.75 – 18.00); Fe (1.05 – 33.12); Ni (0.75 – 16.82); Cu (0.03 – 0.08); and Pb (0.001 – 0.003). Cadmium, chromium and selenium were below detectable levels. The results are considered generally low in terms of the essential elements except in the cases of Ca and Zn in milk; and Fe and Ni in the baked products. The levels of Cu are too low that none of the food could be considered a good dietary source of the metal. The lead levels are too low in comparison with the standards set by the Food Standards of Australia and New Zealand (FSANZ), indicating that the analyzed samples are not polluted with lead and are safe for human consumption.

Keywords: Essential metals, Toxic metals, Low concentrations, Milk, Baked products

Introduction

Metals are significant in nutrition, either for their essential nature or their toxicity (Khaniki and Reza, 2005). The essential trace metals are those whose deficiency reproducibly results in impairment of a function from optimal to sub-optimal conditions (Mertz, 1970). Both the essential and toxic metals occur at trace levels, < 50 mg/kg, in food, but the toxic ones are deleterious even at the trace levels.

The essential metals in human and animal nutrition include Ca, Fe, Co, Cu, Mn, and Zn. Those known to have deleterious effects, or are toxic include Cd, Pb, and Hg (Kirk and Sawyer, 1991). The most serious incidents of toxicity of trace metals to humans have involved ingestion of contaminated food (Radojevie and Bashkin, 1999). However, cumulative poisoning due to ingestion of food containing minute quantities of these toxicants over long periods is probably rare (Kirk and Sawyer, 1991).

Under natural conditions, trace toxic metals can be found in minute and variable but measurable amounts in food, drinking water and ambient air because metals constitute part of the earth's crust. Thus, their sources in food are mainly from the environment (Nriagu, 1990). Dissolved pollutants in the soil are absorbed by plants and they may either cause injury to the plants or pass through the food chain to man. Cadmium in food has been reported to arise largely from natural sources, especially from atmospheric deposition, subsequent entry into water and uptake by aquatic organisms and use of super phosphate fertilizers (MAFF, 1973; 1981). Lead from water and airborne sources have been shown to accumulate in agricultural areas leading to increased concentrations in agricultural products and farm animals (ATSDR, 2005). Metals present in atmospheric aerosols, rainwater or fog, may be deposited on plant surfaces. Unlike most organic pollutants, which may be broken down, metals remain undegraded and are eventually leached into surface and ground waters and may end up in drinking water (Reilly, 1985; Kirk and Sawyer, 1991).

Processed food may be contaminated with trace heavy metals dissolved from processing equipment, such as tinplate, foils, solders, galvanized iron or cheap glazes (Reilly, 1985; Kirk and Sawyer, 1991), and frying pans. Grain milling may lead to higher metal content of floor (IARC, 1990), and packaging materials may introduce trace metals into foods.

Human population is directly affected through the food chain due to bioaccumulation in plants and subsequent transfer into the food chain (Radojevie and Bashkin, 1999).

Contamination can be transferred to animals through direct exposure, polluted water, crops grown on soil irrigated with sewage water, grazing plants irrigated with industrial effluents and feeding from recycled animal waste (Muller, 1980; Norman and Edmonson, 1990)). This is eventually transferred to milk and meat.

Contamination can reach baked products from the flour and by exposure or during processing. Therefore, we set out to determine the levels of metals in milk and backed products to evaluate the level of contamination and the safety of consumption of those products in the light of the current levels of pollution in the total environment.

Materials and Methods

Sample collection: Five brands of powdered milk and four each of evaporated milk, bread, meat pie and sausages, a total of twenty-one samples, were purchased from different shops in Nsukka and Enugu both in Enugu State, Nigeria.

Sample preparation and analysis: The bread, meat pie and sausage samples were pulverized using mortar and pestle. 5 g of each food type were weighed in an evaporating dish and dried at 102^{o}C until constant weight was obtained in order to determine the moisture content.

1 g of each sample was weighed in a 50 mL beaker. 10 mL conc. HNO_3 was added. The beaker was covered with evaporating dish and the mixture was heated up to 80^{o}C for about 30 mins. After cooling, 5 mL $HClO_4$ (70%) were added, and heated again with occasional shaking until white fumes evolved and the solution became clear. After cooling, the digest was transferred into 50 mL volumetric flask, using 1:1 HCl to rinse the beaker. The solution was made up to mark with de-ionized water.

A blank solution was prepared by taking 10 mL HNO_3 plus 5 mL $HClO_4$ through the same process as in the sample preparation and making up to 50 mL with de-ionized water. All reagents were Analar grades. All glasswares were washed with detergent, rinsed with tap water and finally with de-ionized water. Metal standard solutions were prepared from 1000 ppm stock solutions of the metals analyzed for.

Metal analyses: The concentration of the sample blank solution, standard solutions, and the sample solutions were measured on a Unicam 919 atomic absorption spectrophotometer using an air – acetylene flame. With the concentrations of the metals in the sample solutions obtained, the concentrations of each element in the food samples were then calculated as follows: [M] = C x V / W, where [M] is concentration in mg/kg in the food sample, C = concentration in sample solution, V = Volume of sample solution [mL], and W = weight of sample [g].

Results and Discussion

The moisture contents of the various food types shown in Table 1 have the following ranges: 2.57 to 4.30% with mean of 3.57% in powdered milk; 63.87 to 69.49% and mean of 66.03% in evaporated milk; 27.46 to 30.76%, and mean of 28.84% in bread; 22.96 to 38.76% with mean of 31.96% in meat pie and 24.26 to 27.04% with mean of 26.35% in sausages.

Table 1: Percentage moisture content of milk and baked products

Milk and Baked Products	% Moisture
Powdered milk	3.59 ± 0.63
Evaporated milk	66.03 ± 2.30
Bread	28.84 ± 1.83
Meat pie	31.96 ± 6.81
Sausages	26.35 ± 1.40

The mean metal concentrations are shown in Table 2, while Table 3 shows the range of values in the various food types. Cadmium, chromium and selenium were below their respective detection limits in all the samples.

The most abundant metal is calcium, an essential macronutrient with mean values in the range of 29.12 in sausages to 7894.45 mg/kg, wet matter, in powdered milk. Milk is one of the richest sources of calcium (Weaver and Plawecki, 1994). Zinc, another essential metal is next in abundance, with mean values in the range of 2.75 in sausages to 18.00 mg/kg, wet matter, in powdered milk. The range of determined values of calcium and zinc in the various brands of powdered milk (Table 3) compared favourably with the value of 9400 mg/kg Ca and 17 mg/kg Zn, quoted on one of the brands analyzed. Powdered milk is a rich source of calcium and zinc. Iron is more concentrated in the baked products-bread, meat pie and sausages. Mean values range from 13.15 in sausages to 33.12 in bread. The zinc levels of bread in this study were higher than the value of 2.93 mg/kg reported by Onianwa *et al.* (2001). The concentrations of lead in the various food items ranging from 0.001 – 0.003 mg/kg fall within the safe limits. Guideline values for Pb in milk and sausages recommended by the German Federal Health Agency in mg/kg, fresh weight, are 0.03 and 0.25 mg/kg respectively (Merian, 1991). The lead level in milk was also lower than 0.55 mg/kg reported by Zamir and Hussain (2001). The lead content of bread was also lower than 0.01 – 0.03 mg/kg reported by Awofolu (2004). However, Awofolu showed that his bread samples were exposed to atmospheric depositions in motor parks and high traffic areas. Our samples were well packaged and were bought from shops. Moreover, there is less vehicular emission in Enugu and Nsukka compared to Lagos, a mega-city.

The recommended values of lead in and on foodstuffs (sausages, potatoes, and wheat grains) were 0.25, 0.25 and 0.3 mg/ kg fresh weight, respectively (Merian, 1991). The Australia-New Zealand Food Standards (2003) for contaminants and residues in foods recommended a value of 0.2 mg/kg fresh weight, as the maximum level of lead in cereals, pulses and legumes. Furthermore, the permissible total weekly intake (PTWI) of lead for man (WHO, 1972) was set at 0.05 mg/kg body weight and 3.0 mg/person. The mean concentrations of lead obtained in this study were generally lower than all the recommended standards and are not likely to cause any harm to the consumer of these products

Conclusion: The concentrations of the studied metals were quite low, and except for Ca and Zn in milk and Fe and Ni in the baked products, the food items may not be considered good dietary sources of the essential elements analyzed. The low levels of lead showed that the food samples are safe for human consumption. The data could be considered to represent baseline levels.

References

Agency for Trace Substances and Disease Registry (ATSDR), (2005), Statement on Nickel. US Public Health Service, US Pub. Hlth. And Human Serv., Atlanta, G.A.

Awofolu, O. R., (2004): Impact of Automobile Exhaust on Levels of Lead in a Commercial Food from Bus Terminals, Journ. Appl. Scs., and Environ. Management, 8: 23 – 27

Food standards Australian New Zealand (FSANZ) (2003): Australia-New Zealand Food Standards (Formerly ANZFA). Canberra and Wellington, Standards for

Table 2: Metal concentrations* (mg/kg, wet matter) in samples of milk and baked products

Milk and baked products	Cd	Ca	Cr	Cu	Fe	Pb	Ni	Se	Zn
Powdered Milk	BDL	7894.45±2110.79	BDL	0.08±0.03	1.05±1.03	0.003±<0.001	4.75±2.53	BDL	18.00±3.02
Evaporated milk	BDL	391.36 ± 101.71	BDL	0.04±0.01	1.42±1.18	0.001±<0.001	6.43±1.08	BDL	10.17±2.99
Bread	BDL	202.71 ± 71.22	BDL	0.03±0.01	33.12±5.12	0.001±0.000	8.84±0.49	BDL	5.10 ± 2.16
Meat pie	BDL	29.96 ± 19.65	BDL	0.03±0.01	28.49±9.66	0.002±0.001	14.99±1.20	BDL	5.40 ± 6.02
Sausages	BDL	29.12 ± 6.90	BDL	0.04±0.01	13.15±5.81	0.003±0.001	16.82±0.26	BDL	2.75 ± 1.44

** Mean ± sd, n = 4 except for powdered milk, n = 5. BDL = below detection limit.*

Table 3: Ranges* of metal concentrations (mg/kg, wet matter) in samples of milk and baked products

Milk and baked products	Cd	Ca	Cr	Cu	Fe	Pb	Ni	Se	Zn
Powdered Milk	BDL	6226.44 – 11374.22	BDL	0.06 - 0.13	0.02 - 2.29	0.002 - 0.004	2.13 - 7.84	BDL	14.58 - 22.69
Evaporated milk	BDL	242.53 – 465.83	BDL	0.03 - 0.04	0.43 - 2.30	BDL - 0.002	5.48 - 7.82	BDL	8.12 - 14.55
Bread	BDL	134.42 – 302.91	BDL	0.02 - 0.04	28.20 - 39.84	0.0001	8.15 - 9.29	BDL	3.56 - 8.21
Meat pie	BDL	16.07 – 59.04	BDL	0.03 - 0.04	15.98 - 36.98	0.001 - 0.002	13.94 - 16.52	BDL	1.76 - 14.39
Sausages	BDL	19.12 – 34.83	BDL	0.03 - 0.05	9.38 - 21.81	0.002 - 0.003	16.51 -17.12	BDL	1.66 - 4.8

** Powdered milk (n = 5); others (n = 4). BDL = below detection limit.*

contaminants and Residues. htt://www.fodstandards.gov.au

International Agency for Research on Cancer (IARC), (1990), Monographs on Evaluation of Carcinogenic Risks to Humans, Vol. 49, Chromium, Nickel and Welding, Lyon, France, IARC, WHO, 257 – 445.

Khaniki, J. and Reza, G (2005): Determination of Zinc Content in Iranian Flat Breads, Pakistan Journal of Nutrition, 4 [5]: 294 297.

Kirk, R. S. and Sawyer, R. (1991): Pearson's Composition and Analysis of Foods, 9th Edition, Longman Scientific and Technical, England, 1533pp.

MAFF (1981), Survey of Copper and Zinc in Food. Report of the Steering Group on Food Surveillance. Paper No, 5, London, HMSO.

Merian, E. (1991): Metals and their compound in the environment – Occurrence Analysis and Biological Relevance, VCH, Weiheim. 704p.

Mertz, W. (1970): Some aspects of nutritional trace elements research Fed. Proc., 29, 148.2

Ministry of Agriculture, fisheries and Food (MAFF), (1973), Survey of Cadmium in food, Working Party on the monitoring of Foodstuffs for Heavy Metals, 4th report, London, HMSO.

Muller, Z. O. (1980). Feed from animal wastes: State of knowledge. FAO Animal Production and Health, Paper FAO, United Nations Rome 18p.

Norman, B. B. and Edmonson, A. J. (1990) Sources of Chemicals in animal products, in Winter, C.K., Sieber, N. N. and Nuckton, C. F. (Eds), Chemicals in Human Food Chain. Van Nostrand Reinhold, New York, 74p.

Nriagu, J. O. (1990). Food contamination with Cadmium in the environment, in Nriagu, J. O. Simmons, M.S. (Eds), Food Contamination From Environmental sources, Wiley, New York, vol. 23; pp 59 – 84.

Onianwa, P.G., Adeyemo, O, E., Idowu, O.E., Ogabiela, E.E. (2001). Copper and Zinc Contents of Nigerian Foods and Estimates of the Adult Dietary Intakes. Food chemistry 72:89 – 95

Radojevie, M. and Bashkin, W.N. (1999): Practical Environment Analysis 1st Edition. The Royal Society of Chemistry, Cambridge, 404p.

Reilly, C. (1985). The dietary significance of adventitious iron, zinc, copper and lead in domestically prepared food. Food Additives and Contaminants 2 (3) 209 – 215.

Weaver, C. M. and Plawecki, K. L. (1994). Dietary Calcium: Adequacy of a Vegetarian diet. Am. Journ. Clin. Nutr. 59 (suppl) 12386 – 12415.

WHO (1972): World Health Organization. Evaluation of Certain food Additives WHO Tech. Rep. Ser. 505, Geneva.

Zamir, T. and Hassain, A. (2001): Determination of Lead and Cadmium Level in Powdered Milk in Quetta (Pakistan) by Atomic Absorption Spectrometry. Online Journal of Biological Sciences. 1 [5]: 412 – 413.