

Comparison of Digestion Procedures on Commercial Powdered Soup Samples for the Determination of Trace Metal Contents by Atomic Absorption Spectrometry

MUSTAFA SOYLAK^{1*}, HAKAN COLAK¹, MUSTAFA TUZEN², ORHAN TURKOGLU¹ AND LATIF ELCI³

¹Department of Chemistry, Faculty of Art and Science, Erciyes University, 38039 Kayseri, Turkey

²Chemistry Department, Faculty of Science and Arts, Gaziosmanpasa University, 60250 Tokat, Turkey

³Chemistry Department, Faculty of Science and Arts, Pamukkale University, 20020 Denizli, Turkey

(Received: August 2, 2005; Accepted: October 7, 2005)

ABSTRACT

The concentrations of copper, manganese, zinc, iron and aluminum in commercial powdered soup samples produced in Turkey were determined using flame and graphite furnace atomic absorption spectrometry. We compared wet, dry and microwave digestion procedures for the digestion of the soup samples. The microwave digestion procedure for the soup samples was demonstrated to be most effective due to its simplicity and quick results. The accuracy of the method was checked against a standard reference material (SRM 8418 Wheat Gluten). Contents of investigated trace metals in soup samples ranged between 0.41 and 4.78 $\mu\text{g/g}$ for copper, 1.29 and 49.4 $\mu\text{g/g}$ for manganese, 1.26 and 22.5 $\mu\text{g/g}$ for zinc, 4.62 and 61.7 $\mu\text{g/g}$ for iron, and 6.86 and 547.7 $\mu\text{g/g}$ for aluminum. The results were compared with values reported in the literature.

Key words: powdered soup, metal, human health, atomic absorption spectrometry, microwave digestion

INTRODUCTION

Trace metals such as copper, iron, and zinc, among others, while considered essential for normal body functions, are toxic at high concentrations. Moreover, the difference between the ranges of what is essential and what is toxic for the body is often very small. Also certain metal ions, e.g., aluminum and lead, play toxic roles in biochemical reactions on our body. Due to the dual positive and negative roles and the toxicity of trace metals in terms of both human health and the environment, we performed for this study an analysis of trace metal levels in various environmental and food samples⁽¹⁻⁵⁾. Accurate and adequate food composition data are invaluable to estimate the intake adequacy of essential nutrients and assess exposure risks from the consumption of toxic non-essential metals⁽⁶⁾. The main sources of trace elements in foods include soil, agricultural practices, manufacturing processes and environmental sources such as traffic pollution and industrial activities.

The dried foods sector, which includes the commercial powdered soup industry, holds an important place in our country and around the world⁽⁷⁻¹²⁾. Soups represent groups of dried foods and play an important role in people's diet^(13,14). The consumption of powdered soups is high in Turkey. For example, a traditional Turkish soup called tarhana is prepared by mixing wheat flour, yoghurt, yeast and a variety of cooked vegetables, salt and spices. Tarhana soup is especially important in our country in the diets of children

and the elderly⁽¹⁵⁾. According to our survey of relevant literature, while many studies have been done on the organic components of powdered soups^(8-10,16), few^(13,16) were found that address the trace metal contents of commercial powdered soups.

Wet and dry ash procedures represent the two main methods by which traces metals are digested in food samples. However, these procedures are slow and time-consuming, result in analyte loss, are complicated in nature, and frequently run a high risk of contamination. The wet digestion procedure requires the heating of a large volume of concentrated acid in an open beaker. The digestion of food samples using microwaves in trace metal analysis prior to their detection by AAS or ICP-MS has become very popular during the past decade⁽¹⁷⁻¹⁹⁾. Microwave digestion is simple, rapid and reliable for the digestion of a variety of sample matrices. It is a closed system with considerably reduced chemical use and considerably reduced potential hazards, as well as costs. Microwave digestion techniques are widely applied to decompose such food items such as tea⁽²⁰⁾, mushrooms^(19,21), honey⁽²²⁾, wheat⁽²³⁾, fish⁽²⁴⁾, medicinal herbs⁽²⁵⁾ as well as others⁽²⁶⁾.

In this study, the authors compare the efficacy of differing digestion procedures (wet and dry ashing and microwave digestion) on commercial soup samples. The contents of copper, manganese, zinc, iron and aluminum in soup samples produced in Turkey were determined by flame and/or graphite furnace atomic absorption spectrometry after microwave digestion.

* Author for correspondence. Tel & Fax: +90-352-4374933;
E-mail: soylak@erciyes.edu.tr

MATERIALS AND METHODS

I. Apparatus

A Perkin Elmer Analyst 700 atomic absorption spectrometer equipped with graphite furnace and flame unit was used in the experiments. A deuterium background corrector was used for background corrections. The operating parameters for the elements were set as recommended by the manufacturer (Table 1). For flame measurements, a 10-cm long slot-burner head, a lamp and an air-acetylene flame were used.

Argon was used as the inert gas for graphite furnace measurements. Pyrolytic-coated graphite tubes (Perkin Elmer part no. B3 001264) with a platform were used for aluminum determinations by GFAAS. Samples of 20 μL plus 5 μL of 10000 mg/L $\text{Mg}(\text{NO}_3)_2$ as matrix modifier during the study were injected into the graphite furnace using a Perkin Elmer AS-800 autosampler. The signals were measured as peak areas. We defined absolute sensitivity by the characteristic mass of each element, giving a peak absorbance of 0.0044 and 17 pg for Al. During our analyses, the internal argon flow rate through the graphite tube was 250 mL/min; gas flow was interrupted during atomization. Sample volume, ramp and hold times for the drying, ashing, atomization and cleaning temperatures were optimized prior to analysis in order to obtain the maximum absorbance with minimum background.

A Milestone Ethos D closed vessel microwave digestion system (maximum pressure 1450 psi, maximum temperature 300°C) was used. Teflon reaction vessels were used in all digestion procedures. Reaction vessels were cleaned with 5 mL of concentrated nitric acid before each digestion.

II. Reagents

All reagents were of analytical reagent grade unless otherwise stated. Double distilled deionised water (Milli-Q Millipore 18.2 M Ω -cm resistivity) was used for all dilutions. HNO_3 and H_2O_2 were of suprapure quality (E. Merck, Darmstadt). All plastic and glassware were cleaned by soaking in diluted HNO_3 (1+9, v/v) and rinsed with distilled water prior to use. The element standard solutions used for calibration were prepared by diluting stock solutions of 1000 mg/L of each element supplied by Sigma.

III. Sampling

Sixteen different powdered soup samples representing two different manufacturer brands were purchased from local markets in Kayseri and Tokat, Turkey during December 2004. The samples were preserved in their original packaging and stored at 4–5°C until analysis. Samples were dried at 105°C for 2 hr before taking weight measurements.

IV. Digestion Procedures

Three different procedures (dry, wet and microwave) were applied to digest the commercial powdered soup samples. The procedures for each are noted below.

(I) Dry Ashing

One gram of powdered soup sample was placed into a porcelain crucible. Furnace temperature was slowly increased from room temperature to 450°C over a 1-hr period. The sample was ashed for about 8 hr, until a white

Table 1. The analyte ion profiles under atomic absorption spectrometry

FAAS					
Element	Wavelength (nm)	Slit width (nm)	Linear range ($\mu\text{g/mL}$)	Flow Rates of flame gases (L/min)	
				Air	Acetylene
Copper	324.8	0.7	0~4.0	9.5	2.3
Manganese	279.5	0.2	0~2.0	9.5	2.3
Zinc	213.9	0.7	0~1.0	9.0	2.0
Iron	248.3	0.2	0~5.0	9.5	2.3
GFAAS					
				Aluminum	
	Wavelength (nm)			309.3	
	Slit width (nm)			0.7	
				Instrument parameters	
	Argon flow (mL/min)			250	
				Heating program temperature °C (ramp time, hold time (sec))	
	Drying 1			100 (5, 20)	
	Drying 2			140 (15, 15)	
	Ashing			1700 (10, 20)	
	Atomization			2500 (0, 5)	
	Cleaning			2600 (1, 3)	

Table 2. Trace metal contents in SRM 8418 Wheat Gluten reference material ($\mu\text{g/g}$, $n = 4$)

Element	Certified value ($\mu\text{g/g}$)	Found by dry ashing ($\mu\text{g/g}$)	Recovery (%)	Found by wet ashing ($\mu\text{g/g}$)	Recovery (%)	Found by microwave digestion ($\mu\text{g/g}$)	Recovery (%)
Cu	5.94	5.35 ± 0.48^a	90 ± 8	5.64 ± 0.32	95 ± 5	5.78 ± 0.20	97 ± 3
Zn	53.8	51.1 ± 4.5	95 ± 8	52.9 ± 3.6	97 ± 7	53.3 ± 2.5	99 ± 5
Mn	14.3	13.2 ± 1.2	92 ± 8	13.8 ± 1.1	97 ± 8	14.1 ± 0.9	99 ± 6
Fe	54.3	51.6 ± 4.8	95 ± 9	52.3 ± 4.4	96 ± 8	53.9 ± 2.6	99 ± 5
Al	10.8	9.3 ± 0.9	86 ± 8	9.9 ± 0.9	91 ± 8	10.3 ± 0.5	95 ± 5

^aData presented as mean \pm standard deviation.

(or grayish) ash residue was obtained. The residue was dissolved in 5 mL of HNO_3 (25%, v/v) and the mixture, when necessary, was heated slowly to dissolve the residue. The solution was transferred to a 10-mL volumetric flask and made up to volume. Blank digestions were also carried out in the same way.

(II) Wet Ashing

Wet digestion of soup samples was performed using an oxi-acidic mixture of $\text{HNO}_3/\text{H}_2\text{O}_2$ (2/1) (12 mL for a 1.0 g sample). This mixture was heated at 60°C for 4 hr to complete dryness, and then brought to a volume of 10 mL with deionized distilled water. Blank digestion was also carried out in the same way.

(III) Microwave Digestion

One gram of soup sample was digested with 6 mL of HNO_3 (65%) and 2 mL of H_2O_2 (30%) in a microwave digestion system and diluted to 10 mL with deionized distilled water. A blank digest was carried out in the same way.

All digested sample solutions were clear. Digestion conditions for the microwave system were applied as follows: 2 min for 250 W, 2 min for 0 W, 6 min for 250 W, 5 min for 400 W, 8 min for 550 W, and vent for 8 min.

RESULTS AND DISCUSSION

Detection limit was defined as the concentration corresponding to three times the standard deviation of ten blanks. Detection limit values for elements (as measured in milligrams per liter) in flame AAS were found to be 0.004 for Cu, 0.009 for Zn, 0.008 for Fe, 0.007 for Mn. Aluminum was determined with graphite furnace AAS.

In order to compare dry, wet and microwave digestion procedures, SRM 8418 Wheat Gluten - standard reference material was digested by each. Results are given in Table 2. We found dry ash recovery values to be consistently lower than those obtained in wet digestion. Microwave digestion generally achieved the highest recovery values for investigated metal ions in the SRM 8418 Wheat Gluten standards.

Table 3. Comparative efficacy of recovering trace metals in brand A lentil soup using dry ashing, wet ashing and microwave digestion processes, $n = 3$

Element	Dry ashing ($\mu\text{g/g}$)	Wet ashing ($\mu\text{g/g}$)	Microwave digestion ($\mu\text{g/g}$)
Cu	2.70 ± 0.27	2.90 ± 0.26	3.07 ± 0.25
Zn	13.1 ± 1.3	13.5 ± 1.2	13.9 ± 1.1
Mn	3.99 ± 0.35	4.14 ± 0.39	4.43 ± 0.23
Fe	27.6 ± 2.5	28.8 ± 2.3	29.5 ± 1.7
Al	36.9 ± 3.4	38.7 ± 3.1	39.4 ± 2.7

We also compared microwave digestion results against certified values using a *t*-test at a 95% confidence limit (C.L.). We found strong correlation between certified values and our own test values for certified analyte ions obtained through microwave digestion.

All three procedures were checked by running recovery studies. We performed digestions on lentil soup samples (brand A), into which 10 μg of each analyte (for aluminum: 1 μg) was added. Recovery values exceeded 95% for all procedures, with relative standard deviations less than 10% for all investigated elements.

To compare performance measures of the three digestion procedures, lentil soup (brand A) was digested by all three. Results are shown in Table 3. The results achieved by the microwave digestion procedure were superior to the other two, providing a greater degree of accuracy both in terms of time and recovery. We evaluated a conventional microwave oven digestion method for sample digestion prior to determining the level of analytes in soup samples for sample dissolution in closed vessels.

After results were obtained, we analyzed the copper, manganese, zinc, iron and aluminum concentrations in the domestically (Turkey) manufactured commercial powdered soup samples by atomic absorption spectrometry after microwave digestion. All samples were analyzed in quadruplicate. Results are shown in Table 4. All metal concentrations were determined on a wet weight basis.

Copper is recognized as being both vital to and toxic for many biological systems, based on ingested amounts. Copper can enter the food chain through crop soil mineralization, food processing procedures and environmental

contamination (e.g., copper-based pesticides, which are in common use in some countries)⁽⁶⁾. Copper concentrations identified ranged from 0.41 µg/g in tripe soup (brand A) and 4.78 µg/g in lentil soup (brand B), respectively. The level of copper in brand A cream of chicken soup fell below the AAS detection limit. Olivares *et al.*⁽²⁷⁾ have been reported copper concentrations of powdered chicken soup from Chile at 0.70 µg/g. Mean copper levels in cooked vegetable and lentil soups from Kuwait were reported at 127 µg/g by Dashti *et al.*⁽²⁸⁾. Leblanc *et al.* reported that the mean value of copper in cooked soups from France was 0.70 µg/g⁽²⁹⁾.

Zinc is an essential trace element for many biological functions, including proper immune functions⁽³⁰⁾. As can be seen in Table 4, we found the lowest zinc content (1.26 µg/g) in brand A cream of chicken soup and the highest content (22.5 µg/g) in brand A Tarhana soup. The level of zinc in powdered chicken soup produced in Chile was reported as 8.25 µg/g⁽²⁷⁾. Zinc levels in vegetable soups manufactured in Egypt were reported at 32.0 µg/g by Hussein and Brugge-man⁽³¹⁾.

Foods generally containing high levels of manganese include whole grains, nuts, seeds, legumes, pineapple, tea, and leafy green vegetables⁽³²⁾. However, differing levels of manganese in the soil impact the level of manganese in foods. High-tech farming and lime added to soil can lower the manganese levels in certain foods. Manganese levels can also be affected by food processing procedures. The range of manganese levels detected in the soups analyzed fell between 1.29 µg/g, for brand A tripe soup, and 49.4 µg/g, for brand b tripe soup (all values in wet weight). Mangan-

nese fell below the AAS detection limit in brand A's cream-of-chicken and cream-of-mushroom soups. The level of manganese ranged between 1.2 and 2.5 µg/g⁽²⁸⁾ in cooked soup samples from Kuwait and was reported (by Leblanc *et al.*⁽²⁹⁾) at 0.97 µg/g in cooked soups from France.

Iron is an essential element for life and for our diets⁽³³⁾. Low iron levels can cause anaemia. The lowest detectable iron level was found in brand A's tripe soup (4.62 µg/g) and the highest was found in brand A's lentil powder with noodle soup (Ezogelin) (61.7 µg/g). The concentration of iron fell below AAS detection limits in brand A's cream-of-chicken and cream-of-mushroom soups. The average iron content of chicken soup was reported at 4.21 µg/g⁽²⁷⁾.

Aluminum is widespread throughout the natural environment and is present in the air, water, plants and, consequently, throughout the food chain⁽³⁴⁾. Main sources of aluminum in our body include consumed foods and water. Aluminum in food occurs naturally and also through its addition through food additives and by contact with aluminum utensils and containers⁽³⁵⁾. The minimum and maximum aluminum levels found in our study were 6.86 µg/g in brand A's cream of mushroom soup and 547.7 µg/g in brand A's tarhana soup, respectively. Aluminum levels in the investigated soup samples were higher than other analyte metals. The source of aluminum may be the materials in which the soups were packaged. Aluminium in the various soup samples from Kuwait ranged between 3.0 and 5.0 µg/g⁽²⁸⁾ and mean aluminium levels in cooked noodle soup with chicken and cooked chicken-vegetable soup from Granada-Spain were reported as 23.97 µg/g and 19.54 µg/g, respectively⁽³⁶⁾.

Table 4. Copper, zinc, manganese, iron and aluminum levels detected in powdered soup samples (µg/g)

Soup sample	Cu	Zn	Mn	Fe	Al
Brand (A) Cream of vegetable	0.65 ± 0.05	5.91 ± 0.40	2.47 ± 0.15	7.51 ± 0.62	31.3 ± 2.1
Brand (B) Cream of vegetable	1.86 ± 0.12	8.58 ± 0.62	5.22 ± 0.34	11.1 ± 0.9	15.2 ± 1.3
Brand (A) Lentil soup	3.07 ± 0.25	13.9 ± 1.1	4.43 ± 0.23	29.5 ± 1.7	39.4 ± 2.7
Brand (B) Lentil soup	4.78 ± 2.39	21.1 ± 1.5	6.76 ± 0.53	31.6 ± 2.9	246.4 ± 19.5
Brand (A) Lentil powder with noodle (Ezogelin)	4.05 ± 0.32	15.7 ± 1.3	7.41 ± 0.63	61.7 ± 4.2	229.1 ± 10.3
Brand (B) Lentil powder with noodle (Ezogelin)	4.50 ± 0.27	15.7 ± 1.2	6.94 ± 0.50	27.6 ± 2.4	20.1 ± 1.8
Brand (A) Tripe	0.41 ± 0.03	6.84 ± 0.55	1.29 ± 0.11	4.62 ± 0.35	9.70 ± 0.76
Brand (B) Tripe	1.16 ± 0.10	5.89 ± 0.36	49.4 ± 2.5	40.6 ± 3.2	25.1 ± 1.7
Brand (A) Peasant soup with yoghurt (Yayla)	1.14 ± 0.10	9.52 ± 0.65	3.85 ± 0.30	8.88 ± 0.76	16.9 ± 1.4
Brand (B) Peasant soup with yoghurt (Yayla)	1.15 ± 0.10	6.49 ± 0.43	5.38 ± 0.32	6.44 ± 0.47	17.1 ± 1.2
Brand (A) Cream of chicken	BDL ^a	1.26 ± 0.10	BDL	BDL	12.9 ± 0.9
Brand (B) Cream of chicken	0.67 ± 0.05	5.37 ± 0.48	3.21 ± 0.20	7.82 ± 0.60	12.6 ± 1.1
Brand (A) Wheat flour (Tarhana)	3.81 ± 0.25	22.5 ± 1.8	18.2 ± 1.3	27.4 ± 2.4	547.7 ± 32.3
Brand (B) Wheat flour (Tarhana)	2.86 ± 1.90	12.8 ± 1.1	10.5 ± 0.9	22.4 ± 1.9	27.1 ± 2.5
Brand (A) Cream of mushroom	2.83 ± 2.38	4.71 ± 0.35	BDL	BDL	6.86 ± 0.47
Brand (B) Cream of mushroom	1.37 ± 0.12	6.71 ± 0.52	3.64 ± 0.26	11.9 ± 0.9	24.9 ± 2.2

^aBelow detection limit.

The United States Food and Drug Administration (FDA) recommends daily copper, iron, manganese, zinc and aluminum allowances of 3 mg, 18 mg, 10 mg, 50 mg and 8 mg, respectively⁽³⁷⁻³⁹⁾. Considering that a single service portion of cooked soup is prepared using approximately 20 g of powdered soup, analyte element levels in the soup samples examined fall below FDA recommended allowances.

ACKNOWLEDGEMENTS

We want to thank Miss S. Demirel for her help with experiments. The authors are grateful for the financial support of the Unit of the Scientific Research Projects of Gaziosmanpaşa University and the Unit of the Scientific Research Projects of Erciyes University.

REFERENCES

- Orak, H., Altun, M. and Ercag, E. 2005. Survey of heavy metals in Turkish white cheese. *Ital. J. Food Sci.* 17: 95-100.
- Baytak, S. and Turker, A. R. 2005. Bakirin kemik tozu kullanılarak kati faz özütlemeye tekniği ile zenginleştirilmesi ve alevli AAS ile tayini (In Turkish). OR 11. p. 26 IX. Ulusal Spektroskopi Kongresi, Bilkent, 9-11. Haziran, Ankara.
- Skalicka, M., Korenekova, B. and Nad, P. 2005. Copper in livestock from polluted area. *B. Environ. Contam. Toxicol.* 74: 740-744.
- Mello, L. C., Claudino, A., Rizzatti, I., Bortoluzzi, R. L. and Zanette, D. R. 2005. Analysis of trace metals Cu^{2+} , Pb^{2+} and Zn^{2+} in Coastal Marine Water Samples from Florianópolis, Santa Catarina State, Brazil. *J. Brazil. Chem. Soc.* 16: 308-315.
- Zheng, H., Chang, X., Lian, N., Wang, S., He, Q. and Lai, S. 2005. Sulfanilamide-modified nanometer-sized TiO_2 microcolumn for the enrichment of trace Cr (III) and Pb (II). *Ann. Chim.* 95: 601-606.
- Onianwa, P. C., Adeyemo, A. O., Idowu, O. E. and Ogabiela, E. E. 2001. Copper and zinc contents of Nigerian foods and estimates of the adult dietary intakes. *Food Chem.* 72: 89-95.
- Siebert, G., Wiede, H. and Brunke, H. 1983. New standards for rice, instant soups, coffee surrogates and spices. *Lebensmittelindustrie* 30: 401-402.
- Tonogai, Y., Nakamura, Y., Tsuji, S. and Ito, Y. 1987. Detection and determination of polysorbate in powdered soup of instant noodles by colorimetry. *J. Food Hyg. Soc. Jpn.* 28: 427-435.
- Takeda, Y., Abe, Y., Ishiwata, H. and Yamada, T. 2001. Determination method of polysorbates in powdered soup by HPLC. *J. Food Hyg. Soc. Jpn.* 42: 91-95.
- Hoek, H. A. M. 1986. Methods for the determination of total nitrogen and alpha-amino nitrogen in bouillons and consommés-collaborative test. *Alimenta* 25: 93-97.
- www.turkishtaste.com/soups.html
- Mehta, S. K., Malik, A. K., Singh, B. and Rao, A. L. J. 2005. Development of new adsorbent chitin for column preconcentration and spectrophotometric trace determination of Ziram and Zineb in synthetic, commercial samples and food-stuffs. *Talanta* 67: 725-729.
- Kanias, G. D. 1991. Nutrient and other trace-elements in instant soups. *J. Radioanal. Nuc. Chem.* 151: 245-254.
- Kanias, G. D. 1999. Neutron activation analysis of nutrient elements in dried packaged food and comparison with recommended daily allowances. *J. Trace Microprobe Technol.* 17: 111-122.
- Ekinci, R. and Kadakal, C. 2005. Determination of seven water-soluble vitamins in tarhana, a traditional Turkish cereal food, by high-performance liquid chromatography. *Acta Chromatogr.* 15: 289-297.
- Boppel, B. 1976. Lead and cadmium content of food-stuffs. 2. Lead and cadmium content of commercially prepared soups. *Z. Lebensmittel Untersuchung Forschung* 161: 111-113
- Sandroni, V. and Smith, C. M. M. 2002. Microwave digestion of sludge, soil and sediment samples for metal analysis by inductively coupled plasma-atomic emission spectrometry. *Anal. Chim. Acta* 468: 335-344.
- Smith, F. E. and Arsenault, E. A. 1996. Microwave-assisted sample preparation in analytical chemistry. *Talanta* 43: 1207-1268
- Tuzen, M. and Soylak, M. 2005. Mercury contamination in mushroom samples from Tokat-Turkey. *B. Environ. Contam. Toxicol.* 74: 968-972.
- Marchisio, P. F., Sales, A., Cerutti, S., Marchevski, E. and Martinez, L. D. 2005. On-line preconcentration/determination of lead ylex paraguariensis samples (mate tea) using polyurethane foam as filter and USN-ICP-OES. *J. Hazard Mat.* 124: 113-118.
- Zimmermannova, K., Svoboda, L. and Kalac, P. 2001. Mercury, cadmium, lead and copper contents in fruiting bodies of selected edible mushrooms in contaminated Middle Spis region, Slovakia. *Ekol. Bratislava* 20: 440-446.
- Tuzen, M. and Soylak, M. 2005. Trace heavy metal levels in microwave digested honey samples from Middle Anatolia, Turkey. *J. Food Drug Anal.* 13: 343-347.
- Adams, M. L., Chaudri, A. M., Rousseau, I. and McGrath, S. P. 2003. A practical evaluation of microwave and conventional wet digestion techniques for the determination of Cd, Cu and Zn in wheat grain. *Int. J. Environ. Anal. Chem.* 83: 307-314
- van Staden, J. F., van der Merwe, L., Kempster, P. L. and van Vliet, H. R. 2000. Rapid sample preparation using closed-vessel microwave digestion for determining trace metals in fish tissue and sediment. *S. Afr. J. Chem.* 53: 23-27.
- Basgel, S. and Erdemoglu, S. B. 2005. Determination of mineral and trace elements in some medicinal herbs and

- their infusions consumed in Turkey. *Sci. Total Environ.* (In press)
26. Jorhem, L. and Engman, J. 2000. Determination of lead, cadmium, zinc, copper, and iron in foods by atomic absorption spectrometry after microwave digestion: NMKL1 collaborative study. *J. AOAC Int.* 83: 1189-1203.
 27. Olivares, M., Pizarro, F., de Pablo, S., Araya, M. and Uauy, R. 2004. Iron, zinc, and copper: Contents in common Chilean Foods and daily intakes in Santiago, Chile. *Nutrition* 20: 205-212.
 28. Dashti, B., Al-Awadi, F., AlKandari, R., Ali, A. and Al-Otaibi, J. 2004. Macro- and microelements contents of 32 Kuwaiti composite dishes. *Food Chem.* 85: 331-337.
 29. Leblanc, J. C., Guerin, T., Noel, L., Calamassi-Tran, G., Volatier, J. L. and Verger, P. 2005. Dietary exposure estimates of 18 elements from the 1st French Total Diet Study. *Food Addit. Contam.* 22: 624-641
 30. Chan, S. M., Nelson, E. A. S., Leung, S. S. F., Cheung, P. C. K. and Li, C. Y. 2000. Special postpartum dietary practices of Hong Kong Chinese women. *Eur. J. Clin. Nutr.* 54: 797-802.
 31. Hussein, L. and Bruggeman, J. 1991 Zinc analysis of Egyptian foods and estimated daily intakes among an urban population group. *Food Chem.* 58: 391-398.
 32. Onabanjo, O. O. and Oguntona, C. R. B. 2003. Iron, zinc, copper and phytate content of standardized Nigerian dishes. *J. Food Comp. Anal.* 16: 669-676.
 33. Narin, I., Tuzen, M., Sari, H. and Soylak, M. 2005. Heavy metal content of potato and corn chips from Turkey. *B. Environ. Contam. Toxicol.* 74: 1072-1077.
 34. Erdemoglu, S. B., Pyrzyniska, K. and Gucer S. 2000. Speciation of aluminum in tea infusion by ion-exchange resins and flame AAS detection. *Anal. Chim. Acta* 411: 81-89.
 35. Saiyed, S. M. and Yokel, R. A. 2005. Aluminum content of some foods and food products in the USA, with aluminum food additives. *Food Addit. Contam.* 22: 234-244.
 36. Lopez, F. F., Cabrera, C., Lorenzo, M. L. and Lopez, M. C. 2002. Aluminium levels in convenience and fast foods: *In vitro* study of the absorbable fraction. *Sci. Total Environ.* 300: 69-79.
 37. Chen, Y. C., Chen, C. Y., Hwang, H. J., Chang, W. B., Yeh, W. J. and Chen, M. H. 2004. Comparison of the metal concentrations in muscle and liver tissues of fishes from the Erren River, Southwestern Taiwan, after the restoration in 2000. *J. Food Drug Anal.* 12: 358-366.
 38. http://1stholistic.com/Nutrition/hol_nutrition-dosages.htm
 39. http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/aluminum-aluminium_e.html