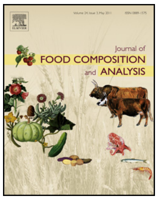
Journal of Food Composition and Analysis 39 (2015) 48–54

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca



Original Research Article

Dietary intake of metals from yogurts analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES)

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ARTICLE INFO

Article history:
Received 6 July 2013
Received in revised form 13 November 2014
Accepted 25 November 2014
Available online 13 January 2015

Keywords:
Food analysis
Food composition
Yogurt
Minerals
Trace elements
Toxic metals
Canary Islands – Spain
Dietary intake

ABSTRACT

The content of 20 macro and trace elements (Na, K, Ca, Mg, Al, B, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Li, Pb, Zn, Ni, Sr and V) were quantified by inductively coupled plasma optical emission spectrometry (ICP-OES) in 72 yogurt samples, purchased in supermarkets in the island of Tenerife (Canary Islands, Spain). Mean concentrations in mg/kg wet weight were: 455 (Na), 1101 (K), 1018 (Ca), 115.1 (Mg), 0.59 (Al), 0.07 (B), 0.40 (Ba), nd (Cd), 0.002 (Co), 0.02 (Cr), 0.27 (Cu), 0.33 (Fe), 0.52 (Li), 0.02 (Mn), 0.04 (Mo), 0.01 (Ni), 0.002 (Pb), 0.02 (V), nd (Sr), and 2.79 (Zn). Daily consumption of yogurt (58.6 g/child/day and 42.1 g/adult/day) contributes to the dietary intake of essential metals and trace elements, mainly Ca (6.0% in children, 4.8% in adult women, and 4.3% in adult men) and Zn (2.0% in children, 1.2% in adult women, and 1.7% in adult men). The levels of metals detected did not reveal any toxicological risk for consumers.

1. Introduction

Yogurt is the coagulated milk product resulting from lactic acid fermentation through the action of lactic acid bacterias (LAB) usually *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (Meydani and Ha, 2000; BOE, 2003; El-Bakri and El-Zubeir, 2009). Worldwide, consumers are increasingly accepting the nutritional properties and beneficial effects of yogurt on human health (De la Fuente et al., 2003; Rinaldoni et al., 2009; Abdulkhaliq et al., 2012). This milk derivative contributes considerably to the intake of nutrients such as proteins and vitamins B_2 and B_{12}, as well as certain minerals, mainly Ca, Mg, and Zn (Starska et al., 2011; Abdulkhaliq et al., 2012; Wang et al., 2012; Rey-Crespo et al., 2013). Knowledge of the beneficial effects of milk derivatives has led manufacturers to produce a wide range of yogurts with different flavors (plain, flavored, sweetened, with fruits, juices and other natural products), textures and consistencies (firm, liquid, shakes, smooth, frozen) in response to consumer preferences (BOE, 2003; De la Fuente et al., 2003; Rinaldoni et al., 2009; Olugbuyiro and Oseh, 2011). Moreover, yogurt and other fermented dairy products are considered to stabilize the intestinal flora and reduce the blood cholesterol level (Meydani and Ha, 2000; Adolfsson et al., 2004; Navarro-Alarcón et al., 2011). In addition, some studies have confirmed a preventive effect of yogurt against colon cancer (Meydani and Ha, 2000).

In the Canary Islands, dairy products have risen to prominence as an essential food for some consumer groups, mainly children and the elderly (Marrero et al., 2004). The Canary Islands Nutrition Survey (ENCA), carried out between 1997 and 1998, determined average, daily yogurt consumption of 58.6 g/person/day for children in the Canary Islands. Yogurt consumption in adults of this community makes up 45.7 g/person/day, consumption in men being lower (44.8 g/person/day) than in women (46.7 g/person/day) (ENCA, 2000). Likewise, the Spanish Agency for Food Safety and Nutrition (AESAN) established the average daily yogurt consumption in the Spanish population with 58.17 g/person/day for children from 7 to 12 years and 40.1 g/person/day for adults over the age of 17 (AESAN, 2006).

Diet constitutes an important source of metals in humans (Cabrera et al., 1995; Coni et al., 1996; Bordajandi et al., 2004; Al Othman, 2010; Hernández Rodríguez et al., 2011; Martorell et al., 2011; Mir-Marqués et al., 2012; Ravelo et al., 2012). Several metals

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http://dx.doi.org/10.1016/j.jfca.2014.11.013
0889-1575/

like Ca, Cu and Fe are essential elements for living organisms and necessary for proper of living organisms by forming part of enzymes. Other metals, such as Cd and Pb, constitute non-essential, toxic elements of particular concern as food contaminants for their potential toxicity even at low concentrations (Rubio et al., 2012). Due to the importance of the mineral and trace element present in yogurts, several studies have been carried out to determine their levels by using graphite furnace atomic absorption spectrometry (GF-AAS) (Ayar et al., 2009; Bilandzic et al., 2011), flame atomic absorption spectrometry (FAAS) (Kaya et al., 2008; Navarro-Alarcón et al., 2011), inductively coupled plasma optical emission spectrometry (ICP-OES) (Tarakci and Dag, 2013), inductively coupled plasma-mass spectrometry (ICP-MS) (Potorti et al., 2013; Keykdal et al., 2011), INNA or X-ray fluorescence spectrometry (XRF) (Avegliano et al., 2011; Rinaldoni et al., 2009). Among the available analytical techniques to quantify the elements present in milk and dairy derivatives, inductively coupled plasma optical emission spectrometry (ICP-OES) is a multi-element technique that combines qualities such as relatively low detection limits, high capacity for simultaneous and precise determinations in short times over wide concentrations ranges. Sample preparation is a critical step in quantitative analysis and a methodology is considered adequate if it is fast, reproducible, safe, free of contamination and requires low reagent consumption. In general, microwave digestion has been frequently used, as it is very effective, with a reduced digestion time and good reproducibility (Güler, 2007). Analysis of mineral contents allows to evaluate the nutritional quality of milk derivatives and to estimate their contribution to the different recommended daily intake (RDI) of metals. Moreover, the quantification of toxic metals in foods facilitates the assessment of consumption associated risks, thus representing a constituent of any food safety program. The European Commission Regulation (EC) No. 1881/2006 has set maximum levels for certain contaminants such as Cd and Pb in different foods. Maximum levels of toxic metals were not fixed for yogurt but for the milk used in its elaboration.

The study of metal contents of yogurts represents a valuable field of research, indispensable for both safety assessment as well as knowledge of their nutritional value. The objectives of this study were (1) to analyze the contents of 20 metals (Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Pb, V, Sr, and Zn) in two types of yogurt (plain and flavored) from three different dairy product manufacturers on the island of Tenerife (Spain), (2) to assess the yogurt-derived intake of essential metals and their contribution to the RDIs, and (3) to evaluate the intake of toxic metals and their contribution to the corresponding Provisional Tolerable Weekly Intake (PTWI) and Tolerable Dairy Intake (TDI).

2. Material and methods

2.1. Sampling

A total of 72 yogurt samples was purchased between September 2011 and May 2012 at different supermarkets in the island of Tenerife (Canary Islands, Spain). Two types of yogurt, including plain and flavored, were analyzed, both from 3 distinct manufacturers (A, B, C). Thus, 24 samples per manufacturer corresponded to 12 plain and 12 flavored yogurts. After transport to the laboratory, all yogurt samples were stored at 4 °C until further processing.

2.2. Sample treatment and analysis

Twenty grams of every homogenized yogurt sample were weighed out and filled into individual porcelain capsules. The samples were desiccated in a thermoregulated vacuum oven (Nabertherm Inc., USA) at 70 °C for 72 h. They were then subjected to pyrolysis in a muffle furnace (Nabertherm Inc, USA) by gradually raising the temperature 450 °C, which was maintained for 48 h. The resulting white ash was dissolved in a solution of 1.5% nitric acid (Merck, Darmstadt, Germany), which was completed to 25 mL (Luis et al., 2011).

Before sample preparation, all laboratory materials used were washed with Acationox laboratory cleaning agent (Merck, Darmstadt, Germany) to avoid contamination and remove any possible trace metals, kept in 5% nitric acid for 24 h, and then washed with milli-Q quality water (Millipore, Bedford, MA, USA).

The minerals in samples were determined by ICP-OES using a Thermo Scientific iCAP 6000 series spectrometer (Waltham, MA, USA). This reference technique for metal determination is highly sensitive with excellent data reproducibility (Rubio et al., 2012). The settings were as follows: approximate RF power, 1.2 kW; gas flow (nebulizer flow; auxiliary flow), 0.5 L/min; pump rate, 50 rpm; stabilization time 0 s. All analyzes were performed in duplicate.

The quality controls used in this work were chosen by the criterion of method accuracy. This was established by the average recovery obtained with reference material measured under reproducible conditions. To this end, the reference materials 1549 SRM Non-Fat Milk Powder, 1515 SRM Apple Leaves and 1573a SRM Tomato Leaves from the National Institute of Standards and Technology (NIST) (Gaithersburg, MD USA) were used. Recovery rates obtained from the reference materials were over 96.5% (Table 1). Instrumental detection and quantification limits in terms of reproducibility, were calculated as three and ten times the standard deviation (SD) resulting from analysis of 15 targets of acid digest (IUPAC, 1995) are detailed in Table 2.

2.3. Statistical analysis

Normal sample distribution was tested using the Kolmogorov–Smirnov and Shapiro–Wilk tests (Xu et al., 2002) while the Levene test was used to determine homogeneity of variance (Pan, 2002). Because the data did not follow a normal distribution, we applied the non-parametric test of Kruskal–Wallis, which allows discrimination of significantly different, individual samples, and the Mann–Whitney test to decide whether there were significant differences between both types of yogurt (Choy et al., 2001). Values of $p < 0.05$ were considered statistically significant. Samples were grouped for analysis according to the type of yogurt and the manufacturer.

3. Results and discussion

In the present study, 4 macroelements (Na, K, Ca, Mg) and 16 trace elements (Al, B, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Li, Pb, Zn, Ni, Sr and V) were analyzed in samples of yogurt. Table 3 shows the mean concentrations and standard deviations for each of the 20 metals in both evaluated types of yogurt (plain vs flavored).

With the exception of Fe, Li, and V, plain yogurt got the highest metal contents. The macroelement K was found to be the quantitatively most outstanding of the analyzed minerals with levels between 1067 mg/kg in natural and 1135 mg/kg in flavored yogurt. The remaining macronutrients followed the sequence of concentration $Ca > Na > Mg$. It was detected that there were significant differences between the concentrations of plain and flavored yogurts ($p < 0.05$).

Furthermore, Zn was the most abundant trace element in both types of yogurt (3.10 and 2.47 mg/kg in plain and flavored yogurt, respectively) followed by the other microelements, ranked in descending order, $Al > Ba > Li > Fe > Cu > B > Mo > Mn > Cr >$

Table 1
Quality control of the method.

Reference material	Element	Certified value[a,b] (mg/kg)	Obtained value[a] (mg/kg)	Recovery (%)
SRM 1549 non-fat milk powder	Na	0.497 ± 0.010[c]	0.51 ± 0.1[c]	102.6
	K	1.69 ± 0.03[c]	1.7 ± 0.02[c]	100.6
	Ca	1.30 ± 0.05[c]	1.31 ± 0.03[c]	100.8
	Mg	0.12 ± 0.003[c]	0.116 ± 0.001[c]	96.7
	Al	2.00[d]	1.98 ± 0.01	99
	Co	0.0041[d]	0.004 ± 0.02	97.6
	Cu	0.7 ± 0.1	0.68 ± 0.0	97.1
	Fe	1.78 ± 0.10	1.77 ± 0.05	99.4
	Mn	0.26 ± 0.06	0.27 ± 0.02	103.8
	Mo	0.34[d]	0.33 ± 0.005	97.1
	Pb	0.019 ± 0.003	0.019 ± 0.05	97.4
	Zn	46.1 ± 2.2	46 ± 0.11	99.8
SRM 1515 Apple Leaves	B	27 ± 2	26.5 ± 0.02	98.1
	Ba	49 ± 2	48 ± 0.05	98
	Ni	0.91 ± 0.12	0.86 ± 0.19	94.5
SRM 1573a tomato leaves	Cd	1.52 ± 0.04	1.45 ± 0.09	95.4
	Cr	1.99 ± 0.06	1.91 ± 0.10	96.0
	V	0.835 ± 0.01	0.84 ± 0.02	100.6

[a] Mean ± standard deviation.
[b] Confidence interval: 95%.
[c] Concentration in mass fraction (%).
[d] Information values.

V > Ni > Co > Sr in plain yogurt and Li > Al > Fe> Ba > Cu > B > Mo > Mn > V > Cr > Ni > Co > Sr in flavored yogurt.

Statistical analysis revealed no significant differences between the two types of yogurt for almost all of the studied metals except for the minerals B, Ba, and Zn. Ca and other substances such as casein might inhibit the absorption of Zn. However, a study by Rosado et al. (2005), demonstrated that there is no such evidence but the consumption of yogurt even increases Zn uptake by approximately 50–68%.

The detected Sr levels were below the quantification limit (0.001 mg/kg). On the other hand, both types of yogurt were found to contain considerable quantities of the metals Al, Li, Fe, and Ba. Some authors suggest this to be due to contamination during the technological procedures (processing, packaging, transport) applied to manufacture these milk derivatives. Thus, the milk comes into physical contact with various tools and equipments which are made of alloys of the mentioned metals (Tokusoglu et al., 2004; Abdulkhaliq et al., 2012).

Table 2
Detection and quantification limits.

Element and wavelength	Detection limit (LOD) (mg/L)	Quantification limit (LOQ) (mg/L)
Na (589.6 nm)	1.097	3.655
K (769.9 nm)	0.565	1.884
Ca (317.9 nm)	0.58	1.955
Mg (279.1 nm)	0.583	1.943
Al (167.0 nm)	0.004	0.012
B (249.7 nm)	0.003	0.012
Ba (455.4 nm)	0.001	0.005
Cd (226.5 nm)	0.0003	0.001
Co (228.6 nm)	0.0006	0.002
Cr (267.7 nm)	0.003	0.008
Cu (327.3 nm)	0.004	0.012
Fe (259.9 nm)	0.003	0.009
Li (670.8 nm)	0.005	0.013
Mn (257.6 nm)	0.002	0.008
Mo (202.0 nm)	0.0007	0.002
Ni (231.6 nm)	0.0007	0.003
Pb (220.3 nm)	0.0003	0.001
Sr (407.7 nm)	0.0007	0.003
V (310.2 nm)	0.001	0.005
Zn (206.2 nm)	0.002	0.007

With respect to toxic metals, the Commission Regulation (EC) No. 1881/2006 has set a maximum level for Pb in yogurt of 0.02 mg/kg (EC, 2006). In this study, mean contents of Pb in the analyzed yogurt samples ranged between 0.001 mg/kg in plain yogurt and 0.003 mg/kg in flavored yogurt; thus, Pb concentrations did not exceed the legally set limit in any of the analyzed samples.

The European legislation does not set a limit for Cd in yogurt. However, similar to Sr, contents of this toxic metal was below the quantification limit (0.001 mg/kg).

Table 4 shows the mean concentrations (mg/kg ± SD) of the 20 analyzed elements in yogurts, allocated to the manufacturers. The names of the manufacturers were replaced with letters A–C. Our data revealed that the yogurts produced by manufacturer A had the highest mean concentrations of essential and trace elements other

Table 3
Mean content ± standard deviation of macro and trace elements in yogurt samples (mg/kg wet weight).

Element	Plain yogurt ($n = 36$)	Flavored yogurt ($n = 36$)
Macroelements		
Na	462 ± 59	447 ± 54
K	1135 ± 111	1067 ± 61
Ca	1080 ± 110[b]	952 ± 70[b]
Mg	121 ± 18	109 ± 20
Trace elements		
Al	0.72 ± 0.57	0.45 ± 0.27
B	0.08 ± 0.05[b]	0.05 ± 0.02[b]
Ba	0.53 ± 0.38[b]	0.28 ± 0.19[b]
Co	0.002 ± 0.001	0.002 ± 0.001
Cr	0.02 ± 0.01	0.02 ± 0.01
Cu	0.29 ± 0.08	0.25 ± 0.07
Fe	0.31 ± 0.08	0.34 ± 0.19
Li	0.49 ± 0.26	0.55 ± 0.30
Mn	0.02 ± 0.004	0.02 ± 0.01
Mo	0.04 ± 0.01	0.03 ± 0.01
Ni	0.01 ± 0.003	0.01 ± 0.004
Sr	<0.003[a]	<0.003[a]
V	0.02 ± 0.01	0.02 ± 0.01
Zn	3.10 ± 0.85[b]	2.47 ± 0.21[b]
Cd	<0.001[a]	<0.001[a]
Pb	0.003 ± 0.003	0.001 ± 0.001

[a] Nd, not detected (below quantification limit).
[b] Statistical significance ($p < 0.05$).

Table 4
Mean concentration ± standard deviation of macro and trace elements in yogurt samples from different manufacturers (mg/kg wet weight).

Metal	Manufacturers		
	A	B	C
Macroelements			
Na	505 ± 53[a]	438 ± 44[a]	421 ± 33[a]
K	1107 ± 92	1066 ± 103	1130 ± 86
Ca	1027 ± 97	1026 ± 124	1000 ± 127
Mg	136 ± 12[a]	111 ± 14[a]	98 ± 11[a]
Trace elements			
Al	0.67 ± 0.54	0.35 ± 0.08	0.74 ± 0.52
B	0.05 ± 0.02	0.05 ± 0.02	0.10 ± 0.05
Ba	0.35 ± 0.25	0.28 ± 0.1	0.58 ± 0.45
Cd	0.001 ± 0.00	0.001 ± 0.00	0.001 ± 0.00
Co	0.002 ± 0.001	0.002 ± 0.001	0.002 ± 0.00
Cr	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.003
Cu	0.26 ± 0.07	0.28 ± 0.07	0.26 ± 0.1
Fe	0.38 ± 0.23	0.30 ± 0.07	0.30 ± 0.07
Li	0.61 ± 0.54	0.51 ± 0.26	0.45 ± 0.2
Mn	0.03 ± 0.01	0.02 ± 0.002	0.03 ± 0.004
Mo	0.05 ± 0.004	0.03 ± 0.003	0.03 ± 0.01
Ni	0.02 ± 0.004	0.01 ± 0.001	0.01 ± 0.002
Sr	0.55 ± 0.19	0.43 ± 0.14	0.33 ± 0.09
V	0.03 ± 0.004	0.02 ± 0.01	0.02 ± 0.01
Zn	2.54 ± 0.22	2.71 ± 0.28	3.10 ± 1.1
Cd	0.001 ± 0.00	0.001 ± 0.00	0.001 ± 0.00
Pb	0.001 ± 0.001	0.002 ± 0.001	0.003 ± 0.002

[a] Statistical significance ($p < 0.05$).

than the metals Al, B, Ba, Cd, Co, Cu, Pb, and Zn while the lowest metal concentrations were detected in the yogurts produced by manufacturer B with the exception of Cu. Differences in Na and Mg levels between both types yogurts or manufacturers were significant ($p < 0.05$). These results confirm that the mineral composition in yogurt can vary according to the manufacturer and, therefore, affect dairy product quality (Olugbuyiro and Oseh, 2011). Hence, metal contents can vary with the applied physical and chemical production techniques for yogurt processing.

Table 5 presents a comparison of mean levels of the essential and toxic metals in the yogurt samples obtained in this study with the results published by other authors. Metal contents in yogurt vary widely between countries (Musaiger et al., 1998; Park, 2000; Güler, 2007; Ayar et al., 2009; Crivineanu et al., 2009; Sanal and Güler, 2010; Llorent-Martínez et al., 2012; Zamberlin et al., 2012). On the whole, essential metal and trace element contents of the yogurt samples from this study were within the concentration ranges set in Jaén (Spain) (Llorent-Martínez et al., 2012), although the detected V contents (0.02 mg/kg) were considerably higher. The largest metal contents were detected by Güler (2007) in Turkey. Metal content in yogurt is recognized to reflect the mineral composition of the milk (the raw material of this product). Several authors have shown that the milk composition may vary with the characteristics of the animal (breed, age, lactation stage, genetic background, feeding) (Park, 2000; Ayar et al., 2009; Enb et al., 2009; Rey-Crespo et al., 2013).

Table 6 shows a comparison between yogurt mineral contents detected in this study and other, published food composition findings (Senser and Scherz, 1999; Mataix-Verdú et al., 1998; Elmadfa et al., 2001; Farrán et al., 2004; Moreiras et al., 2006; Ara, 2007;). The herein obtained concentration ranges were lower for macro- as well as microelements (except Cu) than the ones presented in the mentioned works.

The daily requirements (recommended daily intakes, RDIs) for the adult Spanish population have been established with 1500 mg Na/day, 3100 mg K/day, 900–1000 mg Ca/day, 300 mg Mg/day for women and 350 mg/day for men, 1.1 mg Cu/day, 18 mg Fe/day for women and 9 mg/day for men, 1.8 mg Mn/day for women and 2.3 mg/day for men, 7 mg Zn/day for women and 9.5 mg/day for men, 25 mg Cr/day for women and 35 mg/day for men, and 45 mg Mo/day (FESNAD, 2010).

To assess the contribution of essential metals ingested through yogurt consumption to the RDIs for the population of the Canary Islands (1 yogurt/day = 125 g yogurt/day), we used the data of daily yogurt consumption (58.6 g/child/day and 42.1 g/adult/day) established by the Canary Nutrition Survey (ENCA, 2000). The dietary intake of each element was estimated multiplying the concentration of the element in yogurt by the mean consumption of this food (Avegliano et al., 2011). Table 7 shows the daily intake of essential elements from consumption of yogurt and their contribution to the corresponding RDIs.

Table 5
Comparison of macro and trace elements in yogurts from different countries[a]

Metal	Musaiger et al. (1998)	Park (2000)	Güler (2007)	Ayar et al. (2009)	Crivineanu et al. (2009)	Sanal and Güler (2010)	Llorent-Martínez et al. (2012)	Zamberlin et al. (2012)	This study (2013)
Al	–	3.54–4.97	6.98–8.57	3.52–8.06	0.293–0.543	6.17	0.1–0.8	–	0.19–2.04
B	–	–	18.2–19.6	–	–	23.7	–	–	0.02–0.18
Ba	–	–	1.29–1.64	–	–	–	0.04–0.14	–	0.08–1.35
Ca	1670	1287–1405	1455–2134	–	–	–	–	2000	796–1270
Cd	–	–	1.00–1.01	–	0.002–0.015	0.22	Nd[b]	–	<0.001
Co	–	–	1.38–1.40	Nd–0.033	0.001–0.003	–	Nd–0.015	–	0.001–0.002
Cr	–	–	0.43–1.23	–	0.010–0.017	–	0.006–0.06	–	0.01–0.05
Cu	0.4	0.30–1.09	0.65–1.96	–	0.075–1.727	–	0.035–0.18	Tr[c]	0.16–0.46
Fe	3	1.02–1.96	5.65–7.62	–	0.434–1.772	–	1.5–3.6	0.1	0.2–1.05
K	1290	1417–1630	511–554	–	–	–	–	280	946–1269
Li	–	–	–	–	0.002–0.008	–	–	–	0.19–1.2
Mg	134	148–149	587–838	–	–	–	–	19	78.5–158
Mn	0.3	0.28–0.35	0.93–0.95	–	0.018–0.03	–	0.02–0.22	Tr	0.02–0.04
Mo	–	–	0.87–1.28	–	–	–	0.035–0.075	–	0.02–0.06
Na	750	732–736	520–5147	–	–	–	–	80	356–588
Ni	–	–	1.96–10.1	–	0.013–0.022	1.94	0.006–0.03	–	0.01–0.02
Pb	–	–	0.11–1.30	0.06–0.14	0.018–0.097	3.22	Nd[b]–0.007	–	<LOQ–0.01
Sr	–	–	1.11–1.81	–	0.016–0.084	–	–	–	<0.003
V	–	–	–	–	–	0.97	0.0005–0.008	–	0.01–0.03
Zn	–	3.37–4.10	6.85–9.00	–	0.404–5.05	–	2.6–4.5	0.7	2.09–4.65

[a] All data are expressed in mg/kg on a fresh weight basis.
[b] Not detected (below quantification limit).
[c] Values expressed as traces.

Table 6
Metal contents comparison of yogurt samples obtained in this study and those included in some tables of food composition.[a]

Na	K	Ca	Mg	Cu	Fe	Mn	Zn	Reference
460–550	1550–2060	1210–1300	120–130	Tr[b]–0.1	0.5–2	Tr[b]–0.4	5.9–16	Mataix-Verdú et al. (1998)
500	1550	1200	120	0.1	0.5	0.03	3.8	Senser and Scherz (1999)
480	1570	1200	120	–	0.1	–	–	Elmadfa et al. (2001)
850–1070	1810–2560	1070–1370	150–160	–	1–3	–	6	Farrán et al. (2004)
650–800	2400–2800	1210–1420	142–143	–	0.9–1	–	5.2–5.9	Moreiras et al. (2006)
400–800	1500–2800	1200–1420	100–143	–	0.4–0.9	–	5.4	Ara (2007)
455	1101	1018	115	0.27	0.33	0.02	2.79	Our study

[a] Data are means expressed in mg/kg on a fresh weight basis.
[b] Values expressed as traces.

In general, plain yogurts offer greater contributions to the recommended intakes than flavored ones. Because yogurt consumption is higher in children than in adults, the contributions to the various intakes are also higher in this population. With regard to macroelements, Ca in yogurt showed the highest contribution to the daily intake (6.0% in children, 4.8% in adult women and 4.3% in adult men, according to ENCA, and 14.1% in women and 12.7% in men consuming a cup of yogurt of 125 g daily) followed by Mg, K, and Na. These results confirm that the consumption of yogurt in the population aged 6–9 years favors dietary intake of Ca and, therefore, contributes to its role in bone formation. Marrero et al. (2004) have shown that low yogurt consumption can be associated with insufficient Ca intake in a specific age group, basically in elderly, thus increasing the risk of osteoporosis.

Zn in yogurt was found to be the trace element with the highest contribution to the daily intake (2.0% in children, 1.2% in adult women and 1.7% in adult men, according to ENCA, and 3.7% in women and 5.0% in men consuming a cup of yogurt of 125 g daily) followed by Cu, Fe, and Mn. Noteworthy, contributions to the recommended intakes are significantly different in women and men. The contribution of yogurt to Cr and Mo intake were found to be very low.

Also, in this study, we evaluated, using the ENCA data, the contribution of eating yogurt to toxic metal intake. Al, Li, and Ba were the metals that presented the highest intakes with their relative contributions. The average intake of Al in the population of the Canary Islands, estimated by the ENCA-established yogurt consumption, was 34.4 μg/day for children (aged 6–17) and 24.8 μg/day for adults (over 17). This intake represents 0.7% and 0.3%, respectively of the reference value (1 mg/kg bw/week) established by the EFSA (European Food Safety Authority) in 2011 (González-Weller et al., 2010; EFSA, 2011; Arnich et al., 2012). The estimated intake of Li was 30.5 μg/day and 21.9 μg/day for children and adults, respectively while the estimated intake of Ba was 23.7 μg/day for children and 17 μg/day for adults. No baseline data exist for both metals, Li and Ba, to compare with our results. The estimated intake for B through yogurt consumption was 3.9 μg/day and 2.8 μg/day for children and adults, respectively. These data are well below the reference value (0.16 mg/kg bw/day) established by the EFSA (2004), the contribution being 0.1% and 0.03% in both groups of the Canary Islands' population under study. For Ni, the estimated intake was 0.66 μg/day for children and 0.46 μg/day for adults. This intake represents 0.2% and 0.1%, respectively of the tolerable daily intake (TDI) set at 8 μg/kg bw/day by the EFSA (EFSA, 2005).

The estimated intake of Pb through yogurt consumption was, based on the ENCA data, 0.12 μg/day and 0.08 μg/day for children and adults, respectively. In 2010, EFSA established a TDI of Pb of 0.5 μg/kg bw/day (EFSA, 2010; Cigdem et al., 2013). In consequence, yogurt consumption on the Canary Islands contributes with 0.7% for children and 0.3% for adults to these Pb intake limits.

Intakes of Cd and Sr through yogurt proofed to be negligible. The estimated intake of V was 1.2 μg/day and 0.9 μg/day for children and adults, respectively. There are no reference values for this metal to compare with our data. For Co, the estimated intake was 0.135 μg/day for children and 0.1 μg/day for adults. Notably, no reference value for the tolerable intake was set for this metal either.

Table 7
Mean dietary intake (mg/day) of yogurt and contribution (%) to the daily requirements of macroelements and trace elements for children and adults in the Canary Islands.

Metal	Consume according to ENCA[b]						Eating a cup of 125 g yogurt/day		
	Children			Adults			Intake	Contribution	
	Intake	Contribution		Intake	Contribution			Female	Men
		Female	Men		Female	Men			
Macroelements									
Na	26.6	2.0	2.0	19.2	1.3	1.3	56.8	3.8	3.8
K	64.5	2.1	2.1	46.4	1.5	1.5	138	4.4	4.4
Ca	59.6	6.0	6.0	42.9	4.8	4.3	127	14	13
Mg	6.7	2.2	2.7	4.8	1.4	1.6	14.4	4.1	4.8
Trace elements									
Cu	0.02	1.7	1.7	0.01	1.0	1.0	0.03	3.1	3.1
Fe	0.02	0.2	0.1	0.01	0.2	0.1	0.04	0.5	0.2
Mn	0.001	0.1	0.1	0.001	0.04	0.1	0.003	0.1	0.2
Zn	0.2	2.	2	0.1	1.2	1.7	0.3	3.7	5.0
Cr[a]	0.001	4.9	5.9	0.001	2.5	3.5	0.003	7.5	10.5
Mo[a]	0.002	6	6	0.002	3.3	3.3	0.004	9.7	9.7

[a] Intakes expressed in μg/day.
[b] Data of daily yogurt consumption established by the ENCA (58.6 g/child/day and 42.1 g/adult/day).

4. Conclusions

In this study, the determination of macro and trace elements in plain and flavor yogurts from Canary Islands (Spain) has been carried out using ICP-OES after a dry digestion procedure. Due to the ICP-OES multi-elemental capability, the proposed method permits accurate and precise analysis of metals in yogurts. Taken together, this study confirmed that yogurts are a source of essential dietary elements, particularly Ca and Zn. Metal concentrations in yogurt are conditioned by the composition of the initial milk and the technological procedures used in dairy product processing. Yogurt consumption does not lead to significant intake of toxic metals; therefore, no toxicological risk results from daily consumption of this milk derivative. This study adds to current knowledge on the content of essential and toxic metals in yogurts, providing innovative data on their security and quality.

References

Abdulkhaliq, A., Swaileh, K.M., Hussein, R.M., Matani, M., 2012. Levels of metals (Cd, Pb, Cu and Fe) in cow's milk, dairy products and hen's eggs from the West Bank, Palestine. International Food Research Journal 19, 1089–1094.

Adolfsson, O., Meydani, S.N., Russell, R.M., 2004. Yogurt and gut function. American Journal of Clinical Nutrition 80, 245–256.

AESAN, 2006. Modelo de la dieta española para la determinación de la exposición del consumidor a sustancias químicas. Agencia Española de Seguridad Alimentaria y Nutrición. http://www.aessan.msc.es/AESAN/docs/docs/notas_prensa/modelo_dieta_espanola.pdf (retrieved 15.02.12).

Al Othman, Z.A., 2010. Lead contamination in selected foods from Riyadh City market and estimation of the Daily Intake. Molecules 15, 7482–7497.

Ara, A., 2007. Los alimentos de la A a la Z. EDAF, Madrid, Spain.

Arnich, N., Sirot, V., Riviére, G., Jean, J., Nöel, L., Guérin, T., Leblanc, J.C., 2012. Dietary exposure to trace elements and health risk assessment in the 2nd French total diet study. Food and Chemical Toxicology 50, 2432–2449.

Avegliano, R.P., Maihara, V.A., da Silva, F.F., 2011. A Brazilian total diet study: evaluation of essential elements. Journal of Food Composition and Analysis 24, 1009–1016.

Ayar, A., Sert, D., Akin, N., 2009. The trace metal levels in milk and dairy products consumed in middle Anatolia-Turkey. Environmental Monitoring and Assessment 152, 1–12.

Bilandzic, N., Dokic, M., Sedak, M., Solomun, B., Varenina, I., Knezevic, Z., Benic, M., 2011. Trace element levels in raw milk from northern and southern regions of Croatia. Food Chemistry 127, 63–66.

BOE, 2003. Real Decreto 179/2003, de 14 febrero, el cual aprueba las normas de calidad para yogurt o yoghourt. Boletin Oficial del Estado 42, 6448–6450.

Bordajandi, L.R., Gómez, G., Abad, E., Rivera, J., Fernández-Bastón, M.M., Blasco, J., González, M.J., 2004. Survey of persistent organochlorine contaminants (PCBs, PCDD/Fs, and PAHs), heavy metals (Cu, Cd, Zn, Pb, and Hg), and arsenic in food samples from Huelva (Spain): levels and health implications. Journal of Agricultural and Food Chemistry 52, 992–1001.

Cabrera, C., Lorenzo, M.L., López, M.C., 1995. Lead and cadmium contamination in dairy products and its repercussion on total dietary intake. Journal of Agricultural and Food Chemistry 43, 1605–1609.

Choy, E.H.S., Scott, D.L., Kingsley, G.H., Thomas, A., Murphy, A.G., Staimos, N., Panayi, G.S., 2001. Control of rheumatoid arthritis by oral tolerance. Arthritis and Rheumatism 44, 1993–1997.

Cigdem, E.R., Senkal, B.F., Yaman, M., 2013. Determination of lead in milk and yogurt samples by solid phase extraction using a novel aminothioazole-polymeric resin. Food Chemistry 137, 55–61.

EC (European Commission), 2006. Commission Regulation (EC) N° 1881/2006 of 19 December 2006 setting máximum levels for certain contaminants in foodstuffs. Official Journal of the European Union L364, 5–24.

Coni, E., Bocca, A., Coppolelli, P., Caroli, S., Cavalluci, C., Trabalza, M., 1996. Minor and trace element content in sheep and goat milk and dairy products. Food Chemistry 57, 253–260.

Crivineanu, V., Goran, G.V., Tudoreanu, L., Bianu, E., Dumitrean, L., 2009. Mineral content and heavy metals contamination of some Romanian dairy products. Bulletin of University of Agricultural Sciences and Veterinary Medicine 66, 325–332.

De la Fuente, M.A., Montes, F., Guerrero, G., Juárez, M., 2003. Total and soluble contents of calcium, magnesium, phosphorus and zinc in yoghurts. Food Chemistry 80, 573–578.

EFSA (European Food Safety Authority), 2004. Opinion of the scientific panel on dietetic products, nutrition and allergies on a request from the commission related to the tolerable upper intake level of boron (sodium borate and boric acid). EFSA Journal 80, 1–22.

EFSA (European Food Safety Authority), 2005. Opinion of the scientific panel on dietetic products, nutrition and allergies on a request from the commission related to the tolerable upper intake level of nickel. EFSA Journal 146, 1–21.

EFSA (European Food Safety Authority), 2010. Scientific opinion on lead in food. EFSA Journal 8, 1570.

EFSA (European Food Safety Authority), 2011. Statement on the evaluation of a new study related to the bioavailability of aluminium in food. EFSA Journal 9, 2157.

El-Bakri, J.M., El-Zubeir, I.E.M., 2009. Chemical and microbiological evaluation on plain and fruit yoghurt in Khartoum State, Sudan. International Journal of Dairy Science 4, 1–7.

Elmadfa, I., Aign, W., Muskat, E., Fritzche, D., Cremer, H., 2001. La gran guía de la composición de los alimentos. Integral, Barcelona, Spain.

Enb, A., Abou Donia, M.A., Abd-Rabou, N.S., Abou-Arab, A.A.K., El-Senaity, M.H., 2009. Chemical composition of raw milk and heavy metals behavior during processing of milk products. Global Veterinary 3, 268–275.

ENCA, 2000. Canary Nutrition Survey. Consumers and Health Counseling. Canary Health Service, Canary Islands, Spain.

Farrán, A., Zamora, R., Cervera, P., 2004. Tablas de composición de los alimentos del CESNID. McGraw-Hill Interamericana, Barcelona, Spain.

FESNAD, 2010. Federación Española de Sociedades de Nutrición, Alimentación y Dietética. Ingestas dietéticas de referencia (IDR) para la población española. Actividad dietética 14, 196–197.

González-Weller, D., Gutiérrez, A.J., Rubio, C., Revert, C., Hardisson, A., 2010. Dietary intake of aluminium in a Spanish population (Canary Islands). Journal of Agricultural Food and Chemistry 58, 10452–10457.

Güler, Z., 2007. Levels of 24 minerals in local goat milk, its strained yoghurt and salted yoghurt (tuzlu yogurt). Small Ruminant Research 71, 130–137.

Hernández Rodríguez, L., Afonso Morales, D., Rodríguez Rodríguez, E., Díaz Romero, C., 2011. Minerals and trace elements in a collection of wheat landraces from the Canary Islands. Journal of Food Composition and Analysis 24, 1081–1090.

IUPAC, 1995. International union of pure and applied chemistry, nomenclature in evaluation of analytical methods including detection and quantification capabilities. Pure and Applied Chemistry 67, 1699–1723.

Kaya, G., Akdeniz, I., Yaman, M., 2008. Determination of Cu, Mn, and Pb in yogurt samples by flame atomic absorption spectrometry using dry, wet, and microwave ashing methods. Atomic Spectroscopy 29, 99–106.

Keykdal, O., Rabieh, S., Steingrimsdottir, L., Gunnlaugsdottir, H., 2011. Minerals and trace elements in Icelandic dairy products and meat. Journal of Food Composition and Analysis 24, 980–986.

Llorent-Martínez, E.J., Fernández de Córdova, M.L., Ruiz-Medina, A., Ortega-Barrales, P., 2012. Analysis of 20 trace and minor elements in soy and dairy yogurts by ICP-MS. Microchemical Journal 102, 23–27.

Luis, G., Rubio, C., González-Weller, D., Gutiérrez, A.J., Hardisson, A., Revert, C., 2011. Comparative study of the mineral composition of several varieties of potatoes (*Solanum tuberosum* L.) from different countries cultivated in Canary Islands (Spain). International Journal of Food Science and Technology 46, 774–780.

Marrero, M., Navarro, M.C., Láinez, P., Torres, M., Serra, L., 2004. Ingestión actual de calcio a partir de los lácteos en la población canaria de 6 a 75 años de edad. Datos de la encuesta Nutricional Canaria (ENCA). Reemo 13, 25–29.

Martorell, I., Perelló, G., Martí-Cid, R., Llobet, J.M., Castell, V., Domingo, J.L., 2011. Human exposure to arsenic, cadmium, mercury, and lead from foods in Catalonia, Spain: temporal trend. Biological Trace Element Research 142, 309–322.

Mataix-Verdú, J., Mañas-Almendro, M., Llopis-González, J., Martínez de Victoria-Muñoz, E., Sánchez, J.J., Borregón-Martínez, A., 1998. Tabla de composición de los alimentos españoles. University of Granada, Granada, Spain.

Meydani, S.N., Ha, W.K., 2000. Immunologic effects of yogurt. American Journal of Clinical Nutrition 71, 861–872.

Mir-Marqués, A., Cervera, M.L., de la Guardia, M., 2012. A preliminary approach to mineral intake in the Spanish diet established from analysis of the composition of university canteen menus. Journal of Food Composition and Analysis 27, 160–168.

Moreiras, O., Carbajal, A., Cabrera, L., Cuadrado, C., 2006. Tablas de composición de los alimentos. Pirámide, Salamanca, Spain.

Musaiger, A.O., Al-Saad, J.A., Al-Hooti, D.S., Khunji, Z.A., 1998. Chemical composition of fermented dairy products consumed in Bahrain. Food Chemistry 61, 49–52.

Navarro-Alarcón, M., Cabrera, C., Ruíz, M.D., Olalla, M., Artacho, R., Giménez, R., Quintana, V., Bergillos, T., 2011. Levels of Se, Zn, Mg and Ca in commercial goat and cow milk fermented products: relationship with their composition and probiotic starter culture. Food Chemistry 129, 1126–1131.

Olugbuyiro, J.A.O., Oseh, J.E., 2011. Physico-chemical and sensory evaluation of market yogurt in Nigeria. Pakistan Journal of Nutrition 10, 914–918.

Pan, G., 2002. Confidence intervals for comparing two scale parameters based on Levene's statistics. Journal of Nonparametric Statistics 4, 459–476.

Park, Y.W., 2000. Comparison of mineral and cholesterol composition of different commercial goat milk products manufactured in USA. Small Ruminant Research 37, 115–124.

Potorti, A.G., Di Bella, G., Lo Turco, V., Rando, R., Dugo, G., 2013. Non-toxic and potentially toxic elements in Italian donkey milk by ICP-MS and multivariate analysis. Journal of Food Composition and Analysis 31, 161–172.

Ravelo, A., Rubio, C., González, D., Luis, G., González, J.M., Hernández, C., Gutiérrez, A.J., Hardisson, A., 2012. Contenido en metales (Na, K, Ca, Mg, Fe, Mn, Cu y Zn, en el menú mensual de una guardería pública de Tenerife). Revista Española de Nutrición Comunitaria 18, 77–83.

Rey-Crespo, F., Miranda, M., López-Alonso, M., 2013. Essential trace and toxic element concentrations in organic and conventional milk in NW Spain. Food and Chemical Toxicology 55, 513–518.

Rinaldoni, A.N., Campderrós, M.E., Pérez Padilla, A., Perino, E., Fernández, J.E., 2009. Analytic determinations of minerals content by XRF, ICP and EEA in ultrafiltered milk and yogurt. Latin American Applied Research 39, 113–118.

Rosado, J.L., Díaz, M., González, K., Griffin, I., Abrams, S.A., Preciado, R., 2005. The addition of milk of yogurt to a plant-based diet increases zinc bioavailability but does not affect iron bioavailability in women. Journal of Nutrition 135, 465–468.

Rubio, C., Lucas, J.R.D., Gutiérrez, A.J., González-Weller, D., Pérez, B., Caballero, J.M., Revert, C., 2012. Evaluation of metal concentrations in menthe herbal teas (*Mentha piperita*, *Mentha pulegium* and *Mentha* species) by inductively coupled plasma spectrometry. Journal of Pharmaceutical and Biomedical Analysis 71, 11–17.

Sanal, H., Güler, Z., 2010. Changes in non-essential element concentrations during Torba yoghurt production. Akademik Gida 8, 6–12.

Senser, F., Scherz, H., 1999. Tablas de composición de los alimentos. El pequeño "Souci-Fachman-Kraut". Deustche Forschungsanstalt für Lebensmittelchemie, Garching bei München. Zaragoza. Acribia, Spain.

Starska, K., Wojciechowska-Mazurek, M., Mania, M., Brulinska-Ostrowska, E., Biernat, U., Karlowski, K., 2011. Noxious elements in milk and milk products in Poland. Polish Journal of Environmental Studies 20, 1043–1051.

Tarakci, Z., Dag, B., 2013. Mineral and heavy metal by inductively coupled plasma optical emission spectrometer in traditional Turkish yogurts. International Journal of Physical Sciences 8, 963–966.

Tokusoglu, Ö., Aycan, S., Akalin, S., Kocak, S., Ersoy, N., 2004. Simultaneous differential pulse polarographic determination of cadmium, lead, and copper in milk and dairy products. Journal of Agricultural and Food Chemistry 52, 1795–1799.

Wang, H., Livingston, K.A., Fox, C.S., Meigs, J.B., Jacques, P.F., 2012. Yogurt consumption is associated with better diet quality and metabolic in American men and women. Nutrition Research 33, 18–26.

Xu, P., Huang, S., Zhue, R., Han, X., Zhou, H., 2002. Phenotypic polymorphism of CYP2A6 activity in a Chinese population. European Journal of Clinical Pharmacology 58, 333–337.

Zamberlin, S., Antunac, N., Havranek, J., Samarzija, D., 2012. Mineral elements in milk and dairy products. Mljekarstvo 62, 111–125.