Open Access Journal of Toxicology
ISSN 2474-7599

Research Article
Volume 2 Issue 2 - December 2017
DOI: 10.19080/OAJT.2017.02.555585

Open Acc J of Toxicol

Essential and Toxic Metals in Infant Formula from the European Community

Alejandro Domínguez[1], Soraya Paz[1]*, Carmen Rubio[1], Ángel Gutiérrez[1], Dailos González-Weller[2], Consuelo Revert[3] and Arturo Hardisson[1]

[1]*Área de Toxicología, Facultad de Ciencias de la Salud, Universidad de La Laguna, Spain*

[2]*Servicio de Inspección Sanitaria y Laboratorio, Servicio Canario de la Salud, Spain*

[3]*Área de Fisioterapia, Facultad de Ciencias de la Salud, Universidad de La Laguna, Spain*

Submission: November 01, 2017**; Published:** December 13, 2017

***Corresponding author**: Soraya Paz, Área de Toxicología, Facultad de Ciencias de la Salud, Universidad de La Laguna, Campus de Ofra s/n, 30071 Santa Cruz de Tenerife, Spain, Email: spazmont@gmail.com

Abstract

Infant formulas are intended for children aged 6 - 12 months who, for one reason or another, cannot be breastfed by their mother. These products are made to meet the nutritional needs of children and are therefore, required to be a source of essential metals. However, they may also contain non-essential and toxic metals from the raw material which they are made with and this may be a health risk to children. For this reason, the content of 19 metals (Na, K, Ca, Mg, Fe, Cu, Zn, Cr, B, Ba, Ni, Li, V, Sr, Mo, Mn, Al, Cd, and Pb) were determined in a total of 30 infant formula samples from 15 different brands using inductively coupled plasma atomic emission optical spectroscopy (ICP-OES) with the objective of evaluating the nutritional profile and the toxicological risk derived from the consumption of these products. Ca was the major macroelement with a mean concentration of 4544mg/kg wet weight. As regards trace elements, Fe stands out (55.9mg/kg ww). The mean concentration found for Pb (0.07mg/kg ww) exceeds the maximum limit established in European legislation. The analyzed formulas cover the daily requirements of almost all essential elements. The intake of Pb from the consumption recommended by the manufacturer's means that lead contributes 233% of the Tolerable Daily Intake (TDI). Infant formulas meet the children's nutritional needs, although the concentration of Pb may pose a risk to children's health.

Keywords: Infant formula; Toxic metals; Dietary intake; Toxicological assessment; Toxic risk

Introduction

Breastfeeding is the main source of nutrients for infants since it meets nutritional needs, facilitating the growth and proper development of infants [1,2]. The composition of breast milk confers numerous benefits to the new-borns, reducing the risk of diseases such as enterocolitis or sepsis and strengthening the immune system of infants [2].

Although breast milk is the basis for infant feeding, there may be a number of situations that hinder breastfeeding, such as work, social reasons, medical contraindications or pharmacological treatments that cannot be replaced or withdrawn and pose a risk to the infant breast-feeder [3]. When these situations arise, an alternative diet should be used to meet the nutritional needs of infants, such as infant formulas or preparations. In particular, infant formulas are dairy milk substitutes for the mother's milk intended for children aged 6 to 12 months [4], which is a period when a supplementary feeding is started, and therefore these infant formulas do not need to completely meet the infants' nutritional requirements because this supplementary diet are also a source of nutrients [5].

The macroelements (Na, K, Ca, Mg), are among the essential minerals required for a correct nutrition and are necessary in large quantities, as they play an important role in the human organism. For example, calcium (Ca), which is the major constituent of bone [6,7] or magnesium (Mg), a metal of much importance for maintaining electrolytic balance [8]. On the other hand, trace elements or microelements (Fe, Cu, Cr, Zn, Mn, Mo and Co) are required in smaller amounts but perform numerous physiological functions in the organism. As in the case of iron (Fe), which forms part of the hemoglobin necessary for the transport of oxygen [6,9], it is also added to infant formula to equalize its concentration with the mother's milk, or copper (Cu), which plays an important role as a cofactor in enzymes intervening in multiple metabolic reactions [10].

Although infant formulas are beneficial and safe formulas, they may be a source of contaminants, such as trace elements with no function in the human organism (Sr, Ni, Li, B, Ba and V) or toxic metals (Al, Cd and Pb), which tend to accumulate and are a health risk to children [11,12], who are a more vulnerable group as their excretory capacity is lower than that of an adult, and their body weight is less and they have a weaker immune system [13].

High intakes of non-essential trace elements have toxic effects on health, such as strontium (Sr) for example, which can interfere in numerous biological processes which calcium participates in, due to its affinity for this element, which can lead to childhood rickets [14]. Besides which, Sr can produce insoluble compounds with phosphorus (P) leading to phosphorus deficiency [15,16]. However, there are no known cases of intoxication from these metals arising from diet.

Toxic metals tend to accumulate in the human organism causing multiple toxic effects. Aluminum (Al), a neurotoxic agent, has an affinity for the brain where it accumulates and can cause damage to the central nervous system (CNS). Numerous studies have linked high concentrations of Al in the brain with memory loss and neurodegenerative diseases such as Alzheimer's or Parkinson's [17,18]. Cadmium (Cd) and lead (Pb) are characterized by a high half-life and by their tendency to accumulate in different parts of the body. Excessive intake of Cd and Pb can lead to cardiovascular disease, damage to the nervous system and the bones [19-21].

Since infant formulas are intended for growing children, they need to be safe and meet the nutritional needs of the target population. Therefore, the objectives of this study are to determine the content of macroelements (Na, K, Ca and Mg) and essential elements (Fe, Cu, Zn, Cr, Mn and Mo) in infant formulas to evaluate the nutritional profile as well as the content of non-essential metals (B, Ba, Li, Ni, V and Sr) and toxic metals (Al, Cd and Pb) in order to evaluate the toxicological risk derived from the consumption of these products, taking into account the maximum intake limits and the established legislation.

Materials and methods

Samples

Table 1: Characteristics of analyzed the powered infant formula samples.

Identification	Class	Protein source	Age group	No. Samples	Format	Type of container
M1	Enriched formula	Cow's milk	6-12 months	2	800 g	Paper bag
M2	Enriched formula	Cow's milk	6-12 months	2	400 g	Aluminium tin
M3	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M4	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M5	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M6	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M7	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M8	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M9	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M10	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M11	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M12	Enriched formula	Cow's milk	6-12 months	2	800 g	Aluminium tin
M13	Soya based formula	Soy	6-12 months	2	400 g	Aluminium tin
M14	Hydrolyzed formula	Extensively hydrolysed	6-12 months	2	800 g	Aluminium tin
M15	Hypoallergenic formula	Extensively hydrolysed	6-12 months	2	800 g	Aluminium tin

A total of 30 samples of different types of powdered infant formulas with 15 different brand names, for infants aged between 6 and 12 months, were analyzed. Table 1 shows the characteristics of the samples analyzed.

The samples were purchased in pharmacies on the island of Tenerife (Canary Islands, Spain) between December 2016 and March 2017. They were stored in their original containers until they were opened.

Treatment of samples and analysis

Five grams of each previously homogenized sample were weighed in triplicate in porcelain crucibles (Staatlich, Germany).

How to cite this article: Alejandro D, Soraya P, Carmen R, Ángel G, Dailos GW, Consuelo R, Arturo H. Essential and Toxic Metals in Infant Formula from the European Community. Open Acc J of Toxicol. 2017;2(2): 555585. DOI: 10.19080/OAJT.2017.02.555585.

They were dried in an oven (Nabertherm, Germany) for 24 hours at 70-80 °C. They were then subjected to acid digestion with 65% HNO_3 of reagent purity (Honeybell Fluka, Germany). After digestion, the capsules were placed in a muffle furnace (Nabertherm, Germany) with a time-temperature program of 425 °C-24 hours, with a gradual rise in temperature of 50 °C/hour. The white or greyish white ashes were dissolved in 1.5% nitric acid (HNO_3) and transferred to sterile, hermetic polyethylene containers [7,10,22]. The determination of the metals was performed in a period of less than two weeks after their preparation.

The metal content was determined by inductively coupled plasma atomic emission optical spectroscopy (ICP-OES) using a Thermo Scientific iCAP 6000 series spectrometer (Waltham, MA, USA). The instrumental conditions were as follows: approximate RF power of 1.2kW, gas flow (nebulizer flow, auxiliary flow) of 0.5L/min, pump speed of 50rpm, stabilization time of 0 seconds, wavelength (nm) of each metal: Al (167), B (249.7), Ba (455.4), Ca (317.9), Cd (226.5), Cr (267.7), Cu (327.3), Fe (259.9), K (769.9), Li (670.8), Mg (279.1), Mn (257.6), Mo (202.0), Na (589.6), Ni (231.6), Pb (220.3), Sr (407.7), V (310.2), Zn (206.2).

The quantification limits of the metals were calculated as ten times the standard deviation (SD) obtained from the analysis of 15 targets under reproducible conditions [23], and were as follows: 0.012mg/L (Al), 0.012mg/L (B), 0.005mg/L (Ba), 1.995mg/L (Ca), 0.001mg/L (Cd), 0.008mg/L (Cr), 0.012mg/L (Cu), 0.009mg/L (Fe), 1.884mg/L (K), 0.013mg/L (Li), 1.943mg/L (Mg), 0.008mg/L (Mn), 0.002mg/L (Mo), 3.655mg/L (Na), 0.003mg/L (Ni), 0.001mg/L (Pb), 0.003mg/L (Sr), 0.005mg/L (V), 0.007mg/L (Zn).

In order to ensure the accuracy and precision of the analytical method, a quality control was carried out based on the recovery rate obtained after subjecting the certified reference materials, similar to the matrix under study, to the same treatment procedure as the samples. The reference materials used were BCR-150 and BCR-063R Skim Milk Powder, from the Institute for Reference Materials and Measurements (IRMM), and 1549 Non-Fat Milk Powder from the National Institute of Standards and Technology (NIST). All recovery rates were higher than 98%, and no significant differences ($p = 0$) were found between the certified concentration and the concentration obtained.

Statistical analysis

The statistical analysis was conducted with the IBM Statistics SPSS software for Mac™. First, a normality study was carried out to determine whether the data followed a normal distribution or not by applying the Kolmogorov-Smirnov and Shapiro-Wilk tests [24]. The data which did not follow a normal distribution were analysed by nonparametric tests using the Kruskal-Wallis test [25].

These studies were carried out to study the possible existence of significant differences in the metal content among the different brands of infant formula studied. Values of $p<0.05$ were considered significantly different.

Results

Table 2: Mean metal content and standard deviation found in the analyzed samples without differentiating by brand.

Metal	Mean concentration (mg/kg wet weight)±SD
Macroelements	
K	4107±264
Mg	441±16.5
Na	1668±88.7
Ca	4544±318
Trace elements	
Cr	0.13±0.02
Cu	3.75±0.40
Fe	55.9±7.55
Zn	34.2±1.09
Mn	1.00±0.23
Mo	0.14±0.01
V	0.28±0.16
Ni	0.07±0.04
Li	0.96±0.44
Sr	2.47±0.95
Ba	1.20±0.42
B	1.59±0.21
Toxic metals	
Al	4.02±2.01
Cd	0.01±0.00
Pb	0.07±0.02

Table 2 shows the mean concentrations (mg/kg wet weight) of each metal studied and their obtained standard deviations for all samples without taking the brand into account.

Ca is the major macroelement, with a mean concentration of 4544mg/kg ww wet weight, the remaining macroelements follow the sequence K (4107mg/kg ww)> Na (1668mg/kg ww)> Mg (441mg/kg ww).As for the essential trace elements, the concentrations of Fe (55.9mg/kg ww) and Zn (34.2mg/kg ww) are noteworthy. The mean concentration of Sr at 2.47mg/kg ww is worth mentioning in the case of non-essential trace elements.

Al is the toxic metal with the highest mean concentration of 4.02mg/kg ww, followed by Pb (0.07mg/kg ww) and Cd (0.01mg/kg ww). It should be noted that the mean level of Pb

How to cite this article: Alejandro D, Soraya P, Carmen R, Ángel G, Dailos GW, Consuelo R, Arturo H. Essential and Toxic Metals in Infant Formula from the European Community. Open Acc J of Toxicol. 2017;2(2): 555585. DOI: 10.19080/OAJT.2017.02.555585.

found was above the maximum limit of 0.02mg/kg fresh weight for powdered infant formula established by Regulation (EC) No 1881/2006 of 19 December 2006 which sets the maximum content of certain contaminants in foodstuffs [26].

In addition, Regulation (EU) No 488/2014 amending Regulation (EC) No 1881/2006 sets a maximum limit of 0.01mg/kg fresh weight for powdered infant formula made from protein obtained from cows' milk or from protein hydrolysates, and of 0.02mg/kg fresh weight for infant formula prepared from soy protein either alone or in combination with cow's milk [27]. Therefore, the mean Cd concentration found reaches the maximum limit established in the legislation.

Studies conducted by Kazi et al. [28] and by Winiarska-Mieczan [13] report Pb and Cd concentrations in infant formulas similar to the results obtained here. Although Pandelova et al. [29] found higher Cd levels than those in the present study.

It is noteworthy that both the Pb and Cd levels found in human milk are lower than those recorded in the infant formula studied [30]. However, levels of contaminants in breast milk depend on diet, environment, and habits, with higher levels of both metals being found in female smokers or in those living in contaminated areas [31].

Metal content obtained in each brand studied

Table 3 shows the concentrations of macroelements and essential trace elements (mg/kg wet weight) and their standard deviations obtained depending on the infant formula brand studied.

Table 3: Macroelement and trace element content (mg/kg wet weight) and standard deviation found in each analyzed brand.

Concentration (mg/kg ww)±Standard Deviation										
Sample	Macroelements				Trace elements					
	Ca	K	Mg	Na	Fe	Cu	Cr	Mn	Mo	Zn
M1	3286±281	3052±26.6	398±12.7	398±12.7	41.9±10.4	2.76±0.54	0.11±0.02	0.84±0.15	0.10±0.02	28.9±4.87
M2	4559±257	4520±137	454±18.9	454±18.9	67.4±7.22	4.01±0.44	0.14±0.01	2.02±0.07	0.23±0.01	38.1±0.97
M3	4773±455	4306±360	417±6.07	417±6.07	62.8±12.3	4.02±0.37	0.14 0.02	0.43±0.03	0.07±0.01	38.0±1.14
M4	5221±348	4403±131	457±21.1	457±21.1	57.5±10.8	4.38±0.28	0.12±0.01	0.55±0.03	0.09±0.01	38.1±0.84
M5	5117±149	4411±166	581±15.8	581±15.8	60.1±1.02	3.01±0.03	0.16±0.01	0.96±0.02	0.19±0.00	35.5±0.40
M6	3043±92.0	4091±90.9	405±11.6	405±11.6	35.6±0.86	3.56±0.10	0.08±0.01	0.87±0.01	0.04±0.01	36.4±0.52
M7	4341±198	3650±106	314±35.4	314±35.4	51.2±6.13	3.41±0.17	0.13±0.02	0.46±0.01	0.14±0.00	27.4±0.99
M8	5527±387	4352±295	419±21.4	419±21.4	41.1±6.89	3.61±0.29	0.13±0.01	0.36±0.02	0.07±0.01	33.2±0.22
M9	4628±493	4162±378	369±2.98	369±2.98	48.0±9.76	3.61±0.77	0.12±0.02	0.48±0.05	0.07±0.01	37.2±1.49
M10	4981±260	4462±320	448±44.2	448±44.3	53.5±3.38	3.72±0.38	0.13±0.03	1.04±0.10	0.11±0.01	34.5±1.22
M11	4375±208	34256±240	548±17.7	548±17.7	53.9±1.50	3.85±0.31	0.10±0.01	0.96±0.13	0.19±0.01	37.3±0.89
M12	4483±471	4314±412	577±10.4	577±10.4	65.5±12.6	4.08±0.62	0.13±0.04	0.72±0.05	0.17±0.02	42.8±0.61
M13	4454±543	4391±598	502±11.5	502±11.5	68.9±14.0	2.99±0.53	0.18±0.03	2.20±0.41	0.35±0.05	27.0±0.91
M14	5417±158	4060±195	302±9.75	302±9.75	65.9±2.12	4.66±0.78	0.13±0.01	1.27±1.11	0.26±0.01	27.1±0.28
M15	3960±465	4005±497	419±7.57	419±7.57	65.5±14.3	4.58±0.45	0.11±0.02	1.79±1.24	0.06±0.01	32.1 ±0.96

As for macroelements, the highest concentrations of Ca found in the branded formulas were in M8 (5527mg/kg ww) and M14 (5417mg/kg ww). The highest level of K was in M2, with a concentration of 4520mg/kg ww. Whereas the highest Mg and Na concentrations were observed in M5 (581mg/kg ww) and M13 (2061mg/kg ww), respectively.

How to cite this article: Alejandro D, Soraya P, Carmen R, Ángel G, Dailos GW, Consuelo R, Arturo H. Essential and Toxic Metals in Infant Formula from the European Community. Open Acc J of Toxicol. 2017;2(2): 555585. DOI: 10.19080/OAJT.2017.02.555585.

As regards the essential trace elements, the Fe level determined in the samples of the M1368.9mg/kg wwis noteworthy as are the Zn contents in the M2 and M4samples, with both being 38.1mg/kg ww.

Table 4 shows the mean concentrations (mg/kg wet weight) and standard deviations of the non-essential trace elements and toxic metals found for each analyzed brand.

Sr is the most notable trace element with an average concentration of 5.26mg/kg ww, with the highest concentration being found in M10. Furthermore, it is worth mentioning the mean levels of B and Li found in the M14 were 3.21mg/kg ww and 2.84mg/kg ww, respectively. The statistical analysis confirmed the existence of significant differences in the vanadium content between the different samples analyzed, with the highest mean concentration being determined in M2.

Regarding toxic metals, M7 had the highest level of aluminium which was 7.05mg/kg ww. Besides, the Pb concentration found in M1 is noteworthy, with a mean concentration of 0.09mg/kg ww. The Cd levels, however, were similar in all the analyzed brands, with the exception of M13, whose Cd concentration was the highest with a mean value of 0.02mg/kg ww. This higher concentration of Cd can be explained by the fact that M13 corresponds to the soybean-based infant formula, and that the soybean has the capacity to absorb toxic metals from the soil [32].

Table 4: Non-essential trace element and toxic metal content (mg/kg wet weight) and standard deviation found in each analyzed brand.

Concentration (mg/kg ww)±Standard Deviation									
Sample	Non-essential trace elements						Toxic metals		
	B	Ba	V	Ni	Li	Sr	Al	Cd	Pb
M1	0.93±0.14	0.63± 0.16	0.18±0.32	0.05±0.02	0.54±0.35	1.63±0.18	2.79±0.85	0.01±0.00	0.09±0.01
M2	1.27±0.12	2.26±0.63	0.64±0.64	0.10±0.01	1.52±0.51	1.95±0.06	5.92±1.74	0.01±0.00	0.07±0.01
M3	1.64±0.19	1.43±0.37	0.24±0.19	0.04±0.01	1.33±0.43	1.66±0.10	2.71±1.76	0.01±0.00	0.06±0.01
M4	1.57±0.09	1.49±0.70	0.28±0.08	0.05±0.02	1.32±0.30	1.63±0.06	6.63±2.15	0.01±0.00	0.08±0.01
M5	1.38±0.10	0.92±0.37	0.19±0.19	0.04±0.01	0.76±0.50	2.08±0.16	2.76±0.63	0.01±0.00	0.05±0.01
M6	1.14±0.05	0.39±0.04	0.13±0.03	0.04±0.01	0.42±0.05	2.72±1.19	1.87±1.23	0.01±0.00	0.06±0.01
M7	1.24±0.40	0.51±0.07	0.25±0.12	0.06±0.02	0.42±0.03	3.63±1.59	7.05±7.30	0.01±0.00	0.08±0.04
M8	1.25±0.08	0.68± 0.36	0.24±0.15	0.02±0.01	0.31±0.03	1.78±0.13	1.58±0.76	0.01±0.00	0.06±0.00
M9	1.14±0.25	1.12±0.46	0.10±0.10	0.07±0.00	0.84±0.70	1.39±0.07	4.68±2.20	0.01±0.00	0.07±0.03
M10	1.17±0.09	1.36±0.26	0.24±0.11	0.04±0.02	0.79±0.55	5.26±3.47	4.01±3.94	0.01±0.00	0.08±0.03
M11	1.43±0.37	1.83±1.07	0.29±0.12	0.25±0.37	0.41±0.19	2.00±0.64	2.08±0.50	0.01±0.00	0.06±0.01
M12	2.18±0.25	1.40±0.63	0.27±0.08	0.06±0.01	0.78±0.29	1.12±0.11	4.25±3.42	0.01±0.00	0.07±0.02
M13	2.71±0.51	1.44±0.63	0.35±0.07	0.12±0.01	0.61±0.07	3.60±1.32	3.72±0.44	0.02±0.00	0.06±0.00
M14	3.21±0.13	1.51±0.37	0.37±0.11	0.05±0.01	2.84±1.39	3.68±2.71	6.23±0.42	0.01±0.00	0.07±0.03
M15	1.57±0.42	1.05±0.16	0.40±0.05	0.05±0.00	1.57±1.18	2.98±2.51	4.00±2.75	0.01±0.00	0.08±0.03

Discussion

The daily consumption of infant formula recommended by the manufacturers studied is about 150 grams of milk powder per day. The recommended consumption and the mean concentrations obtained for each metal were taken into account to calculate the estimated daily intake (EDI), as well as its contribution to the recommended daily intake (RDI) and the maximum intake for the infant formulas (Table 5).

Table 5: Estimated daily intake (EDI) and percentage contribution to the maximum and recommended daily intake for each analyzed metal.

Macro elements and essential trace elements				
	Mean conc. (mg/kg) ± SD	EDI (mg/day)[a]	Recommended Daily Intake (RDI)	Contribution (%)[b]
Na	1668±88.7	616	370 mg/day [33]	88
K	4107±264	66.2	700 mg/day [33]	88.2
Ca	1668±88.7	250	525 mg/day [33]	67.6
Mg	441±16.5	682	75 mg/day [33]	130
Cr	0.13±0.02	0.02	5.5µg/day [6]	355
Cu	3.75±0.40	0.56	0.3µg/day [33]	188
Fe	55.9±7.55	8.39	8 mg/day [33]	105
Zn	34.2±1.09	5.13	4 mg/day [33]	128

How to cite this article: Alejandro D, Soraya P, Carmen R, Ángel G, Dailos GW, Consuelo R, Arturo H. Essential and Toxic Metals in Infant Formula from the European Community. Open Acc J of Toxicol. 2017;2(2): 555585. DOI: 10.19080/OAJT.2017.02.555585.

Mn	1.00±0.23	0.15	0.6 mg/day [33]	25
Mo	0.14±0.01	0.02	3µg/day [33]	700
Toxic and non-essential elements				
	Mean conc. (mg/kg) ± SD	EDI (mg/day)a	Maximum values (TDI or TWI)	Contribution (%)b
Ni	0.07±0.04	0.01	2.8µg/kg bw/day [37]	41.7
Sr	2.47±0.95	0.37	0.13mg/kg bw/day [39]	31.7
Ba	1.20±0.42	0.18	200µg/kg bw/day [38]	100
B	1.59±0.21	0.24	0.16mg/kg bw/day [38]	16.6
Al	4.02±2.01	0.6	1mg/kg bw/week [35]	46.9
Cd	0.01±0.00	0.002	2.5µg/kg bw/week [34]	46.7
Pb	0.07±0.02	0.01	0.5µg/kg bw/day [40]	233

[a]Calculated as EDI=Metal concentration(mg/kgww)•Mean consumption (kg/day)., based on a mean consumption of 150 grams a day

[b]Calculated as Contribution(%)= (EDI (mg/day))/(RDI or Maximum values)•100, based on a mean body weight of 9 kilos in the case of TDI and TWI

The Recommended Daily Intake (RDI) values for macroelements and essential trace elements for children aged 7-12 months, established by FESNAD (the Spanish Federation of Nutrition, Food and Dietetic Societies), are as follows: 525mg Ca/day, 700mg K/day, 75mg mg/day, 370mg Na/day, 8mg Fe/day, 4mg Zn/day, 0.3µg Cu/day, 0.6 mg Mn/day, 3µg Mo/day [33], and for chromium set at 5.5µg Cr/day by the Institute of Medicine, Food and Nutrition Board [6].

In view of the results presented in Table 4, the contribution of macroelements from the consumption of the infant formulas studied meets the nutritional requirements of infants from 7 to 12 months of age, with the noteworthy contribution of calcium, which accounts for 129% of RDI, followed by Mg, K and Na, with contribution rates of 88.1%, 88.0% and 68.0%, respectively. As regards the essential trace elements, the nutritional needs of infants are met, exceeding 100% of the RDI for all metals, with the exception of Mn, whose contribution is 25% of the recommended daily intake. However, it must be taken into account that at these ages, the infants start other foods that contribute to nutritional requirements.

In order to evaluate the toxic risk derived from the consumption of these products, a mean body weight of 9kg was used, as well as tolerable daily intake (TDI) or tolerable daily weekly intake (TWI) values established by various institutions, such as:

1. The European Food Safety Authority (EFSA) sets the following tolerable weekly intakes (TWI) for cadmium of 2.5µg Cd/kg body weight/week [34] and for aluminium of 1mg Al/kg body weight/week [35] as well as the following tolerable daily intakes for chromium of 0.3 mg Cr/kg body weight/day [36] and for nickel of 2.8µg Ni/kg body weight/day [37].

2. World Health Organization (WHO) sets the following tolerable daily intakes for boron of 0.16 mg B/kg body weight/day, for barium 0.02 mg Ba/kg body weight/day [38] and for strontium of 0.13mg Sr/kg body weight/day [39].

3. The Spanish Agency for Food Safety and Nutrition (AESAN) has suggested a lead TDI of 0.5µg/kg body weight/day [40], adapted from BMDL01 (Benchmark dose modelling) dosage set by the EFSA [41].

The contribution percentages obtained for non-essential trace elements and for toxic metals (Table 5) are below tolerable daily and admissible weekly daily intake values, with the exception of barium and lead. In the case of barium, a percentage of contribution that is 100% of the TDI was observed, in spite of this, no cases of intoxication from the intake of barium from the diet have been found.

However, in the case of lead, the percentage of contribution is 233% of the TDI far exceeding the tolerable daily intake value. This is an alarming finding, as lead has multiple toxic effects because it is a carcinogenic, mutagenic metal that damages the developing nervous system [41]. Infants, who these products are intended for, are a highly vulnerable group because they are growing, which is why lead can cause irreversible harmful effects [13]. Although some studies have shown that calcium, due to its similar chemical characteristics, interferes with the absorption of lead at the gastrointestinal level [42], it is necessary to introduce greater controls on these products.

Conclusion

The content of macroelements (Na, K, Ca and Mg), trace elements (Fe, Cu, Cr, Zn, Mn, Mo, Ni, Li, B, Ba, V, and Sr) and toxic metals (Al, Cd and Pb) were determined in 30 samples of 15 different brands of infant formula by ICP-OES. The study carried out shows that infant formulas meet the macroelement and essential element nutritional needs of infants aged between 6 - 12 months. The concentration of Pb found in each of the analyzed samples was higher than the maximum limit established in European legislation. The consumption of these products can

How to cite this article: Alejandro D, Soraya P, Carmen R, Ángel G, Dailos GW, Consuelo R, Arturo H. Essential and Toxic Metals in Infant Formula from the European Community. Open Acc J of Toxicol. 2017;2(2): 555585. DOI: 10.19080/OAJT.2017.02.555585.

carry serious risks from a high intake of Pb, which far exceeds the Tolerable Daily Intake (TDI). Therefore, the consumption of these products is not safe. This alarming finding needs to be acted on by the relevant authorities by increasing the controls both on the final products and on the raw materials which are used to make them.

Conflict of interest

The authors declare that they have no conflicts of interests.

References

1. Mead MN (2008) Contaminants in Human Milk. Weighing the Risks against the Benefits of Breastfeeding. Environ Health Perspect 116(10): A427-A434.
2. Choi A, Fusch G, Rochow N, Sheikh N, Fusch C (2015) Establishment of micro methods for macronutrient content analysis in breast milk. Matern Child Nutr 11(4): 761-772.
3. O'Connor NR (2009) Infant Formula. Am Fam Phys 79(7): 565-570.
4. Labiner-Wolfe J, Fein SB, Shealy KR (2008) Infant Formula-Handling Education and Safety. Pediatrics 122(2): S85-S90.
5. Koletzko B, Bhutta ZA, Cai W, Cruchet S, El Guindi M, et al. (2013) Compositional Requirements of Follow-Up Formula for Use in Infancy: Recommendations of an International Expert Group Coordinated by the Early Nutrition Academy. Ann Nutr Metab 62(1): 44-54.
6. IOM (Institute of Medicine) (2001) Panel on Micronutrients. 13, Arsenic, Boron, Nickel, Silicon, and Vanadium. In Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academies Press (US), Washington (DC)
7. Rubio C, Paz S, Ojeda I, Gutiérrez AJ, González-Weller D, et al. (2017) Dietary Intake of Metals from Fresh Cage-Reared Hens' Eggs in Tenerife, Canary Islands. J Food Qual 1-10.
8. Gonzalez-Weller D, Rubio C, Gutiérrez AJ, Pérez B, Hérnandez-Sánchez C, et al. (2015) Dietary Content and Evaluation of Metals in Four Types of Tea (White, Black, Red and Green) Consumed by the Population of the Canary Islands. Pharm Anal Acta 6(10): 1-10
9. Moll R, Davis B (2017) Iron, vitamin B12 and folate. Medicine 45(4): 198-203
10. Luis G, Rubio C, Revert C, Espinosa A, González-Weller D, et al. (2015) Dietary intake of metals from yogurts analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES). J Food Comp Anal 39: 48-54.
11. Ikem A, Nwankwoala A, Odueyungbo S, Nyavor K, Egiebor N (2002) Levels of 26 elements in infant formula from USA, UK, and Nigeria by microwave digestion and ICP-OES. Food Chem 77(4): 439-447.
12. Iwegbue CMA, Nwozo SO, Overah LC, Nwajei GE (2010) Survey of trace element composition of commercial infant formulas in the Nigerian market. Food Addit Contam Part B Surveill 3(3): 163-171.
13. Winiarska-Mieczan A (2009) Assessment of infant exposure to lead and cadmium content in infant formulas. J Elementol 14(3): 573-581
14. Brown CJ, Chenery SRN, Smith B, Mason C, Tomkins A, et al. (2004) Environmental influences on the trace element content of teeth - implications for disease and nutritional status. Arch Oral Biol 49(9): 705-717.
15. Pors Nielsen S (2004) The biological role of strontium. Bone 35: 583-588.
16. González-Weller D, Rubio C, Gutiérrez AJ, Luis González G, Caballero MJM, et al. (2013) Dietary intake of barium, bismuth, chromium, lithium, and strontium in a Spanish population (Canary Islands, Spain). Food Chem Toxicol 62: 856-868.
17. González-Weller D, Gutiérrez AJ, Rubio C, Revert C, Hardisson A (2010) Dietary Intake of Aluminum in a Spanish Population (Canary Island). J Agric Food Chem 58(10): 10452-10457.
18. Hardisson A, Revert C, González-Weller D, Gutiérrez A, Paz S, Rubio C (2017) Aluminium Exposure through the Diet. HSOA JFood Sci Nutr 3(1): 1-10.
19. Rubio C, González-Iglesias T, Revert C, Reguera JI, Gutiérrez AJ, Hardisson A (2005) Lead Dietary Intake in a Spanish Population (Canary Islands). J Agric Food Chem 53(16): 6543-6549.
20. Rubio C, Hardisson A, Reguera JI, Revert C, Lafuente MA, González-Iglesias T (2006) Cadmium dietary intake in the Canary Islands, Spain. Environ Res 100: 123-129.
21. Shaheen N, Irfan NMD, Khan IN, Islam S, Islam MDS, et al. (2016) Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh. Chemosphere 152: 431-438.
22. Hardisson A, Rubio C, Baez A, Martin M, Alvarez R, Diaz E (2001) Mineral composition of the banana (Musa acuminata) from the island of Tenerife. Food Chem 73(2): 153-161.
23. IUPAC (International Union of Puré and Applied Chemistry) (1995) Nomenclature in Evaluation of Analytical Methods including Detection and Quantification Capabilities. Pure Appl Chem 67: 1699-1723.
24. Rubio C, Napoleone G, Luis-González G, Gutiérrez AJ, González-Weller D, et al. (2017) Metals in edible seaweed. Chemosphere 173: 572-579
25. Gutiérrez A, González-Weller D, González T, Burgos A, Lozano G, et al. (2008) Content of trace metals (iron, zinc, manganese, chromium, copper, nickel) in canned variegated scallops (Chlamys varia). Int J Food Sci Nutr 59(6): 535-543.
26. EC (European Commission) (2006) COMMISSION REGULATION (EC) No 1881/2006 of 19 December 2006 setting máximum levels for certain contaminants in foodstuffs. Off J Eur Union L 364/6.
27. EC (2014) COMMISSION REGULATION (EC) No 488/2014 of 12 May 2014 amending Regulation (EC) No 1881/2006 as regards maximum levels of cadmium in foodstuffs. Off J Eur Union L 138/75.
28. Kazi TG, Jalbani N, Baig JA, Afridi HI, Kandhro GA, et al. (2009) Determination of toxic elements in infant formulae by using electrothermal atomic absorption spectrometer. Food Chem Toxicol 47(7): 1425-1429.
29. Pandelova M, Levy Lopez W, Michalke B, Schramm KW (2012) Ca, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, and Zn contents in baby foods from the EU market: Comparison of assessed infant intakes with the present safety limits for minerals and trace elements. J Food Comp Anal 27(2): 120-127
30. Gundacker C, Pietschnig B, Wittmann KJ, Lischka A, Salzer H, et al.(2002) Lead and mercury in breast milk. Pediatrics 110(5): 873-878.
31. Al-Saleh I, Shinwari N, Mashhour A (2003) Heavy Metal Concentrations in the Breast Milk of Saudi Women. Biol Trace Element Res 96(1-3): 21-37.
32. Rizwan M, Ali S, Adrees M, Ibrahim M, Tsang DCW, Zia-ur-Rehman M et al. (2017) A critical review on effects, tolerance mechanisms and management of cadmium in vegetables. Chemosphere 182: 90-105.
33. FESNAD (Federación Española de Sociedades de Nutrición, Alimentación y Dietética) (2010) Ingestas Dietéticas de Referencia (IDR) para la Población Española. Act Diet 14(4): 196-197.
34. EFSA (European Food Safety Authority) (2009) Scientific Opinion of the Panel on Contaminants in the Food Chain on a request from the European Commission on cadmium in food. EFSA J 980: 1-139.

How to cite this article: Alejandro D, Soraya P, Carmen R, Ángel G, Dailos GW, Consuelo R, Arturo H. Essential and Toxic Metals in Infant Formula from the European Community. Open Acc J of Toxicol. 2017;2(2): 555585. DOI: 10.19080/OAJT.2017.02.555585.

35. EFSA (2011) Statement on the evaluation on a new study related to the bioavailability ofaluminum in food. EFSA J 9(5): 2157

36. EFSA (2014) Scientific Opinion on the risks to public health related to the presence of chromium in food and drinking water. EFSA J 12(3): 3595

37. EFSA (2015) Scientific Opinion on the risks to public health related to the presence of nickel in food and drinking water. EFSA J 13(2): 4002

38. WHO (2001) Barium and barium compounds Concise International Chemical Assessment Document, 33. WHO, Geneva, Switzerland.

39. WHO (2011) Strontium and strontium compounds. Concise International Chemical Assessment Document 77: 1-63.

40. AESAN (2012) Report of the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) regarding criteria for the estimation of concentrations for the discussion proposals for migration limits of certain heavy metals and other elements from ceramic articles intended to come into content with foodstuffs. J Sci Commit 16: 11-20.

41. EFSA (2010) EFSA Panel on contaminants in the food chain (CONTAM). Scientific opinión on lead in food. EFSA J 8(4): 1570

42. Hong YC, Kulkarni SS, Lim YH, Kim E, Ha M et al. (2014) Postnatal Growth Following Prenatal Lead Exposure and Calcium Intake. Pediatrics 134(6): 1151-1159.

How to cite this article: Alejandro D, Soraya P, Carmen R, Ángel G, Dailos GW, Consuelo R, Arturo H. Essential and Toxic Metals in Infant Formula from the European Community. Open Acc J of Toxicol. 2017;2(2): 555585. DOI: 10.19080/OAJT.2017.02.555585.