DETERMINATION OF SOME ELEMENT CONCENTRATIONS OF FIRST INFANT MILK FORMULA AND HEALTH RISK ASSESSMENT

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Abstract: Breast milk is suggested as the best method for baby nourishment by The World Health Organization (WHO, 2003). However, in some cases, breastfeeding is not possible due to different metabolic reasons. In such cases, an infant formula that is similar to the breast milk content is designed to meet infant nourishment requirements during the first 6 months after birth. It is important to know the content of infant milk formula for a baby's health. The purpose of this presented study is to determine the elemental (Fe, Cu, Al, Cd, As, Ni, Ba) contents of the four different brands of first infant milk formula sold in the Turkish markets. Elemental contents of samples were identified by Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-OES) after a microwave digestion process. Target hazard quotients (THQ) of analyzed elements were calculated and risk analyses were conducted. According to the results, the hazard indexes (HI) of infant milk formula samples were founded as less than 1 and all samples were included in the low risk group.

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Introduction

Optimum nutrition and good feeding have a significant role in the determination of infants' health, growth and development. Healthy infant nutrition prevents some chronic diseases and reduces infection risks in adults (Michaelsen et al., 2003). Breast milk is suggested as the best method for baby nutrition by The World Health Organization (WHO), but it is not adequate or possible in some cases such as metabolic reasons or increasing nutritional requirements (Mehrnia & Bashti, 2014). In such cases, baby milk formulas which are designed and marketed for feeding to babies are used and they show similar characteristic to breast milk (U.S. Department of Health and Human Services). Infant milks are classified based on nutrient content and numbered according to month. 1st (first infant milk), 2nd (follow-on milk) and 3rd (growing up milk) numbers of milk are suitable for 0-6, 6-9, 9-12 months old babies respectively.

Toxic elements can be taken into the human body in various ways from the atmosphere or foods and they may pose health risks especially for infants. Many developmental problems are directly related to exposure to them. Because of this reason, it is important to know the content of infant milk formula. The elemental contents of milk formula and their influence on baby health is a curious issue (Mehrnia & Bashti, 2014).

Infant milk contains various elements (essential and non-essential) of Fe, Cu, Al, Cd, As, Ni, Ba. There are lots of effects of these elements found in the content of infant milk on the health of a baby. Al, Cd, As, Ni, and Ba are non-essential elements that may cause negative effects on the baby body. Aluminum (Al) damages nervous and skeletal system and causes Parkinson's disease and Alzheimer's disease at a later age (Sipahi et al., 2014; Yalcın et al., 2014). Cadmium (Cd) shows the toxic effect on kidneys and causes bone demineralization (Sipahi et al., 2014). Arsenic (As) is a human carcinogen and causes skin, lung, and bladder cancer (Hong et al., 2014). Ba causes gastrointestinal disturbances and muscular paralysis (Yalcın et al., 2014). Nickel is a known as immunotoxic, neurotoxic, carcinogenic agent so Ni intake shows the toxic effect on the health (Das et al., 2008). Iron (Fe) and Copper (Cu) are essential for human life however, they can show toxic effect at high concentrations. Iron poisoning is a common toxicological effect seen in young children (Boyle, 2016).

There are several literature studies about elemental contents of baby food. Mehrnia et al. (2014), determined four toxic elements (Cd, Ni, Mn, Pb) in the different type of baby food and estimated the daily intakes of toxic elements for children. Odhiambo et al. (2015), determined Cd, Al, Pb, and Ni content in milk infant formula which sold in the Kenyan market. Ljung et al. (2011), studied several elements in breast milk, infant formula, and rice-based baby food. Tripathi et al. (1999), investigated Zn, Cu, Pb, and Cd content of milk and milk products.

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The aim of the present study is to investigate and compare the concentration of Fe, Cu, Al, Cd, As, Ni, and Ba amount of 1st number infant milk formulas sold in Turkey. The health effects of these elements in an infant body were also investigated and the health risk was determined.

Materials and methods

Preparation of the Infant Milk Samples

Infant milk samples were obtained from the local market in Istanbul, Turkey. Samples were prepared for ICP-OES use by a microwave method.

In this method, 0.1 g of infant milk powder was digested with 10 mL of HNO_3 (%65 Nitric acid, Merck KGaA, Darmstadt, Germany) in a microwave digestion system (Berghof MWS 3+) (Figure 1), using the digestion program specified in Table I. The digested and cooled solutions were diluted to 50 mL with distilled water. ICP-OES was used for the analysis of the resultant solutions.

Table 1: Operating conditions for the microwave digestion system

Step	**Temperature (°C)**	**Ramp Time (min)**	**Hold Time (min)**
1	150	10	5
2	160	10	5
3	190	10	10
4	100	3	2

Source: Authors

Figure 1: Microwave digestion system

Source: Authors

Preparation of the Calibration Sets and Elemental Analysis of the Samples

Calibration sets were conducted by using Al, As, Ba, Cd, Cu, Fe, and Ni standard solutions which are obtained from Merck Chemicals (Merck KGaA, Darmstadt, Germany). Inductively coupled plasma - optical emission spectrometry (ICP-OES) is a widely used technique which can determine trace-level element composition and it has a high sensitivity for detecting elements (Sivakumar et al., 2014). In this technique the emission spectra of a sample are used to determine and quantify the element therefore, excitation and/or ionization of the sample is ensured at the high temperatures (Hou & Bradley, 2000).

Figure 2: Inductively coupled plasma optical emission spectrometry (ICP-OES)

Source: Authors

The Perkin-Elmer Optima 2100 DV model ICP-OES equipped with an AS-93 autosampler was used in the experiments (Figure. 2). Measurement conditions were adjusted to a power of 1.45 kW, plasma flow of 15.0 L min^{-1}, the auxiliary flow of 0.8 L min^{-1} and nebulizer flow of 1 L min^{-1}.

Calculation of Estimated Daily Element Intakes

The estimated daily intake of elements (EDIs) was assessed using the daily food consumption of an infant, element concentration, and body weight. The following equation is used in the calculation (Islam et al. 2015).

$$\mathrm{E}DI = \frac{FIRxC}{B_w} \quad (1)$$

Where C is the average concentration of elements in infant milk samples (mg/kg), FIR is the daily food consumption (g/day) and B_w is the body weight (kg). The average weight (B_w) and food consumption amount (FIR) of 0-6-month-old babies are calculated as 5 kg and 120 g, respectively according to the literature study (Sipahi et al., 2014) which indicated the mean weights of 0-2, 2-4 weeks and 2, 4, 6 months old infants. The average concentration of elements (C) are given in Table 2.

Health Risk Calculation

The health risk factor related with infant milk consumption is calculated by using the following Equations (Islam et al., 2015; Shaheen et al., 2016).

$$THQ = \frac{EFrxEDxFIRxC}{RfDxB_w xA_T} \quad (2)$$

$$HI = \sum_i^n THQ_i \quad (3)$$

Where THQ is the target hazard quotient, FIR is the rate of food consumption (g/person/day), RfD is the oral reference dose, BW is the average body weight and AT is the average lifetime (70 years). Exposure frequency (EFr) (180 days/year) and exposure duration (ED) (6 months) were calculated according to 6 months value because of the using 1st number infant milk which consumed by 0-6 months infants in the experimental. The RfD values of Fe, Al, Cd, Cu, As, Ni and Ba are set to be 0.7 (Wu et al., 2016), 1 (Yu et al., 2015), 0.001, 0.04, 0.0003, 0.02, 0.2 mg/kg/d (Shaheen et al., 2016).

Results and discussion

Analysis Results

Elemental analysis results of samples are given in Table 2. The element with the highest concentration among the analyzed elements is Fe (max 41.35 ppm) and followed by Al (max 7.98 ppm). Cu (max 0.36 ppm) and Cd (max 0.25 ppm) contents of the analyzed samples are considerably lower than Fe and Al contents.

Table 2: Element concentrations of infant milk samples

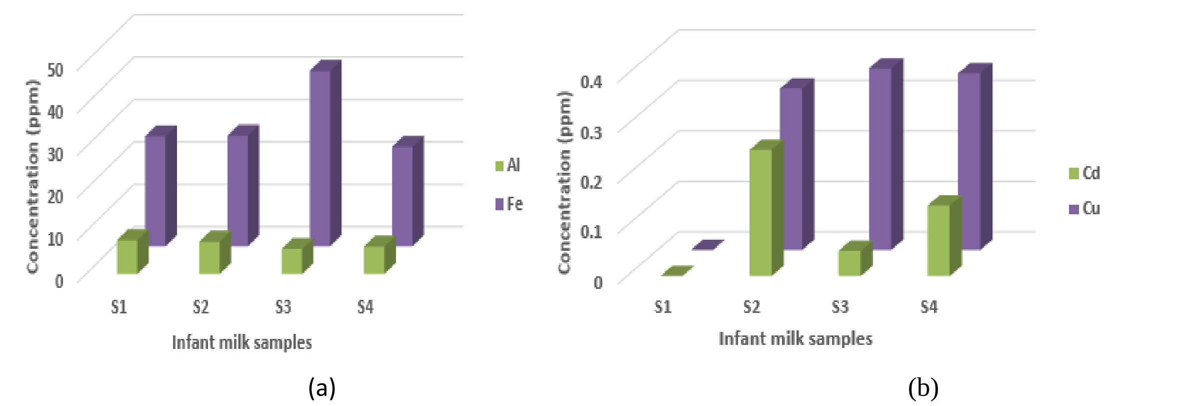
Infant milk samples	Element concentrations (ppm)						
	Fe	Al	Cd	Cu	As	Ni	Ba
S1	25.9	7.98	b.m.l.	b.m.l.	b.m.l.	b.m.l.	b.m.l.
S2	26.5	7.60	0.25	0.32	b.m.l.	b.m.l.	b.m.l.
S3	41.35	5.88	0.05	0.36	b.m.l.	b.m.l.	b.m.l.
S4	23.41	6.44	0.14	0.35	b.m.l.	b.m.l.	b.m.l.

b.m.l. below measurable levels

Source: Authors

The concentration of non-essential elements of As, Ba, and Ni are below the measurable levels in all infant milk samples. For S1, Cd and Cu content cannot be detected when Cd and Cu contents are measured between 0.05-0.25 ppm and 0.32-0.36 ppm, respectively. The Al contents are varied between 5.88 and 7.98 ppm when S1 contains the highest Al amount. The highest Fe and Cu contents are determined for S3. Figure 3 (a) and Figure 3 (b) show the comparison of Fe-Al elements and Cd-Cu elements contents for all samples, respectively.

Figure 3: The comparison of Fe-Al elements (a) and Cd-Cu elements (b) contents for all samples



Source: Authors

Calculation of Estimated Daily Elemental Intakes and Health Risk AssessmentEstimated daily elemental intakes (EDI) of essential and non-essential elements were calculated by using Equation(1). Calculation results for each element were given in Table 3.

Table 3: Estimated daily elemental intakes (mg/kg)

Samples	Fe	Al	Cu	Cd
S1	0.6216	0.1915	-	-
S2	0.6252	0.1824	0.0077	0.0060
S3	0.9924	0.1411	0.0086	0.0012
S4	0.56184	0.1546	0.0084	0.0034

Source: Authors

Equation (2) was used for calculation of THQ values. The trends of THQ values for Fe in the samples are in order to S3>S2>S1>S4 and for Al in the samples are in order to S1>S2>S1=S4. The lowest THQ values are obtained for Cu and the THQ values of Cd element change between 0.0042-0.0211.

Taking the four samples into consideration, Equation (3) was used to estimate the total health risk index (HI) value caused by Fe, Al, Cu, and Cd. The risk assessments of metals taken with infant milk formula consumption were calculated to be within safe limits (THQ<1) and the HI values (sum of individual metal THQ) were calculated in this study.
According to the results of the risk analysis of the elements for 4 samples, the hazard index is found to be less than 1 which is calculated for a 120 g consumption of infant milk and therefore these milk powders have been included in the low-risk group.

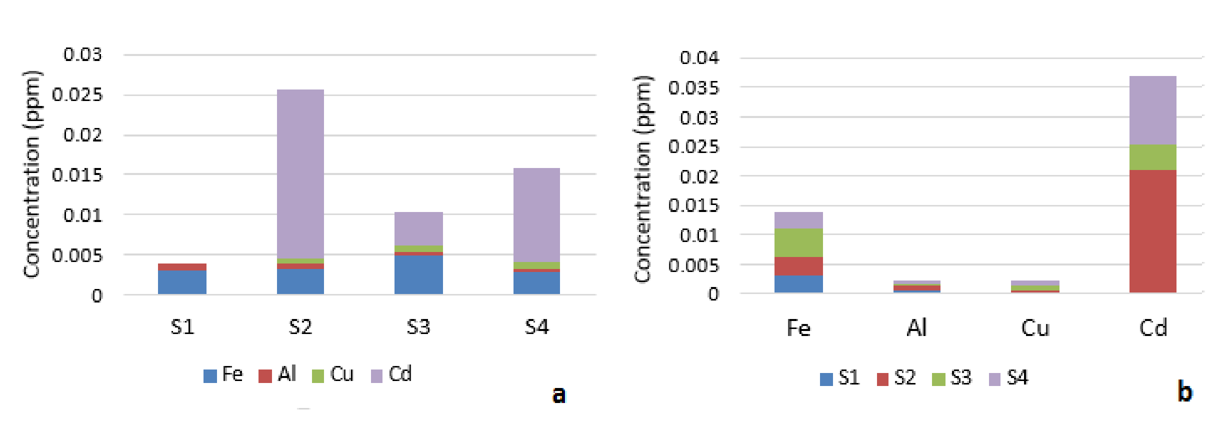
Table 4: THQ and HI calculation

	Target hazard quotient (THQ)				Health Index (HI)
Samples	Fe	Al	Cu	Cd	
S1	0.0031	0.0007	-	-	0.0038
S2	0.0032	0.0006	0.0007	0.0211	0.0256
S3	0.0049	0.0005	0.0008	0.0042	0.0104
S4	0.0028	0.0005	0.0007	0.0118	0.0158

Source: Authors

In Figure 4, the health index of first infant milk formula is shown. The highest HI value was obtained for the S2 sample (Figure 4a) which was followed by S4, S3, and S1, respectively. As seen in Figure 4b, the main reason of the high HI values was the Cd content of samples.

Figure 4: Health index of first infant milk formula



Source: Authors

Conclusion

Contents of some essential (Fe, Cu) and non-essential elements (Al, Cd, As, Ni, Ba) in infant milk samples sold in the local market in Istanbul, Turkey were measured in the present study. The amounts of Fe were significantly higher than other elements in all samples and this is followed by Al, Cu, and Cd respectively. After that, EDI, THQ, and HI values are calculated for the selected infant milk samples. THQ values are estimated for each element and hazard index is determined by using total THQ values of each element that belong to per samples.

The risk groups of samples are classified according to HI values. HI values higher than 1 represents the high-risk group. In the same way, the samples that have a HI value less than 1 are in the low-risk group.

Based on HI values of these elements all analyzed infant milks are in the low-risk group. In conclusion, there is no health risk for the examined infant milks in terms of their elemental compositions.

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