2011 International Nuclear Atlantic Conference - INAC 2011
Belo Horizonte, MG, Brazil, October 24-28, 2011
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-04-5

DETERMINATION OF ESSENTIAL ELEMENTS IN COMMERCIAL BABY FOODS BY INAA

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ABSTRACT

The World Health Organization recommends that infants be breastfeed exclusively at least six months after birth. After this period, it is recommended to introduce complementary foods, in order to meet nutritional amounts, minerals and energy needs of children. Commercial food products intended for infants form an important part of the diet for many babies, so it is very important that such food contains sufficient amounts of minerals. Inadequate complementary feeding is a major cause of high rates of malnutrition in developing countries. In this study, essential elements: Ca, Co, Cr, Cs, Fe, K, Na and Zn levels were determined in seven different commercial food products samples by Instrumental Neutron Activation Analysis. The seven baby food samples were acquired in the markets of São Paulo city. After 8-hour irradiations in the IEA-R1 nuclear research reactor under a thermal neutron flux of 10^{12} n cm^{-2} s^{-1}, the essential elements were determined and the concentrations obtained were lower than the WHO requirements. For validation of the methodology, INCT MPH-2 Mixed Polish Herbs and NIST SRM 1577^{b} Bovine Liver were analysed.

1. INTRODUCTION

Trace elements play an important role in human healthy. Trace amounts of some elements, calcium, iron and zinc, for example, are essential micro nutrients and have a variety of biochemical functions in all living organisms. While these elements are essential, they can be toxic when taken in excess [1]. The World Health Organization recommends that infants be breastfeed exclusively at least six months after birth. After this period, it is recommended to introduce complementary foods, in order to meet the needs of children for their nutritional development [2]. Complementary food is defined as all foods and fluids other than breast milk given to the infant [3].

The ingestion of complementary foods in the child's feeding schedule aims, mainly, to elevate energy and micronutrients quotas, maintaining breast feeding until the child is 12 or 24 months old [4]. If complementary foods are not introduced when a child has reached six months, or if they are given inappropriately, an infant's growth may be compromised [2].

The composition of commercial baby foods can be very different from those foods that make up the diet of the general population and therefore require information on the levels of many elements in these food groups [5].

Complementary foods play a critical role in providing the adequate quantities of many minerals. Inadequate complementary feeding is a major cause for high prevalence of malnutrition in developing countries. Some elements may be a potential health risk when consumed above the tolerable levels of intake for an extended period [3].

Some infant foods, such as commercial baby foods, are deliberate enriched with essential elements, such as zinc and copper to ensure that they provide the nutritional trace elements. Another important factor that must be considered when assessing the exposure of infants to trace elements and heavy metals in their diets is that infants grow and develop very rapidly in their first year of life. Therefore their energy requirements and, hence, their food consumption is on average much higher relative to their body weight than of adults and older children [1].

After six months after birth, the introduction of complementary food is recommended to ensure an adequate intake of minerals. It should however be noted that trace element analysis of infant food only reveals the total content of trace elements, and does not consider differences in bioavailability. From the age of six months, it is probable that the child's diet is gradually supplied or replaced in part with the ordinary family food. A dietary survey of healthy infants from 6-12 month may help in estimating the food intake as well as the dietary sources. However, food sources and cooking practices vary considerably between countries and even within the population in a given country [3].

There are no published data on element content in commercial baby foods marketed in São Paulo city. The objective of this study was to determine essential elements (Ca, Co, Cr, Cs, Fe, K, Na and Zn) content in commercial baby foods by Instrumental Neutron Activation Analysis.

Instrumental neutron activation analysis (INAA) was employed for the precise and accurate element determination, since it is a powerful method for the direct analysis of solid food samples without dissolution, thus eliminating the possibility of contamination. The technique also provides low detection limits for many inorganic constituents. Moreover, the quality control and quality assurance of the technique is also maintained through the use of certified reference materials (CRMs) [6].

2. EXPERIMENTAL

2.1- Description of the commercial baby foods

Commercial baby foods are divided into four different stages, according to the age of children, composition, flavors and textures. The first stage that could be offered as soup to babies after six months allows that babies to discover the food. Thus these foods are composed only by one type of fruit. Stages 1 and 2 are adequate to babies from 6 months, but new flavors and foods are introduced in stage 2. The third stage could be offered to 8 months babies and these foods will be responsible to stimulate the babies to chew. So, in the third stage some food is in pieces, not only in the form of porridge. Finally, the last stage, called junior, is designed to provide nutrition for growth and development of children as well as their adaptation to normal diets. Therefore foods will have flavors similar to those offered during family meals. Table 1 shows the types of commercial baby foods found in the market of São Paulo city.

Table 1. Types of the commercial baby foods

Commercial baby foods	Flavor	Age
Stage 1	One fruit	From 6 months
Stage 2	Two fruit, fruit and milk, salt soup	From 6 months
Stage 3	Salt soup	From 8 months
Junior Stage	Salt soup	From 12 months

2.2 Sample Preparation

In this study seven commercial baby foods were analyzed. All formulas were salty and belonged to Stage 2 (6-8 months).

Table 2 describes the commercial baby food samples analyzed with their codes used in this study.

All samples were collected in the form of soup. The bay food samples were coded and removed from their containers to the polyethylene vials, previously cleaned with deionized H_2O and 10% HNO_3 solution. The samples were stored then in a refrigerator at -4 ºC to maintain the product in adequate conditions.

The samples were freeze-dried during 15 hours at -51°C and a pressure of 49µbar in a freeze-dryer Thermo-Electron Corporation (Modelyo D). After the process of lyophilization, the samples were ground and homogenized in a domestic blender, which was adapted with titanium blades. The percentages of water weight losses during this process varied from 71.1 to 88.1%.

Table 2. Compositions of the commercial baby foods samples

Sample (codes)	Composition
PCL	Meat with vegetables
PFL	Bean soup with vegetables and beet
PFM	Chicken breasts with vegetables and noodles
PCG	Yolk eggs with meat and vegetables
PHFA	Vegetables with chicken breasts
PLM	Meat with vegetables and parsnip
PP	Turkey breasts with vegetables and rice

2.2 Preparation of Ca, Co, Cr, Cs, Fe, K, Na and Zn Standards

Standards of Ca, Co, Cr, Cs, Fe, K, Na and Zn were prepared from appropriate dilutions of their Spex Certiprep stocks solutions. Aliquots (25 – 100 µL) taken from such solutions were pipetted on small sheets of Whatman 40 filter paper and dried under infrared lamp. After drying, these filter papers were placed into to clean polyethylene bags.

2.2 Neutron Irradiations

About 0.2 g of baby food sample weighed in polyethylene bags were irradiated together with element standards for 8 hours under a thermal neutron flux of 4.5 x 10^{12} n cm^{-2} s^{-1} at the IEA-R1 nuclear research reactor of IPEN/CNEN-SP.

After different decay periods, gamma-ray activities of the irradiated samples and element standards were measured with a POP TOP model HPGe detector from EG&G ORTEC with 20% efficiency and 1.9 keV resolution at 1332.49 keV peak of ^{60}Co. The detector is coupled an electronic system composed of multi-channel analyzer, source of high tension, amplifier and a compatible microcomputer. The gamma-ray spectrum was analyzed using the VISPECT2 software. Table 3 presents the nuclear data of the radioisotopes used in this study.

Table 3. Nuclear data for the radioisotopes determined by INAA

Radionuclides used	Half-life	Gamma-ray used keV	Decay time	Counting time
^{47}Ca	4.54 d	1297.09	10 -15 d	7200 s
^{60}Co	5.27 y	1173.2	10 -15 d	7200 s
^{51}Cr	27.7 d	320.08	10-15d	7200 s
^{134}Cs	2,06y	604	10 -15 d	7200 s
^{59}Fe	44.5 d	1099.25	10 -15 d	50000 s
^{42}K	12.36 h	1524.58	5 d	7200 s
^{24}Na	14.96 h	1368.60	5 d	7200 s
^{75}Se	119.77 d	264.66	10 -15 d	50000 s
^{65}Zn	243.9 d	1115.55	10 -15 d	50000 s

3. RESULTS AND DISCUSSION

Instrumental Neutron Activation Analysis (INAA) was applied to determine eight essential elements (Ca, Co, Cr, Cs, Fe, K, Na and Zn) in seven commercial baby food samples. To assess the accuracy and precision methodology two certified reference materials (CRMs) INCT MPH-2Mixed Polish Herbs and NIST-SRM 1577^b Bovine Liver were also analyzed. Table 4 presents the experimental results obtained with the certified values for these elements. Most of the results agreed with the certified values, resulting in relatively good precision and accuracy.

Table 4. Concentration of elements in NIST certified reference materials

Element	Mixed Polish Herbs (INCT-MPH-2)			Bovine Liver (NIST 1577[b])		
	This study (Mean±SD)[a]	RSD (%)	Certified values	This study (Mean±SD)[b]	RSD (%)	Certified values
Ca mg/g	10842 ± 241	2.2	10800 ± 700	<LD	-	116 ± 4
Co µg/g	225 ± 16	7.1	210 ± 25	249 ± 7	2.8	(250)
Cr µg/g	1.69 ± 0.68	4.0	1.69 ± 0.13	489 ± 95	19	-
Cs µg/g	71.3 ± 8.2	11	76.0 ± 7.0	<LD	-	-
Fe mg/g	487 ± 36	7.4	(460)[c]	185 ± 8,2	4.4	(184)
K mg/g	19456 ± 430	2.2	19100 ± 1200	10143 ± 433	4.3	9940 ± 60
Na mg/g	378 ± 15	4.0	(350)	2295 ± 48	2.1	2420 ± 64
Zn mg/g	33.3 ± 1.6	4.9	33.5 ± 2.1	128 ± 8	6.4	(127)

[a]Mean and Standard Deviation of eight determinations <: Limit of detection
[b] Mean and Standard Deviation of seven determinations
[c]Values in parenthesis indicate informative values

The results of essential elements in lyophilized commercial baby foods and *in natura* samples consumed in São Paulo city are shown in Table 5 and Table 6, respectively. The only element mentioned on the labels of these baby food samples was sodium.

Table 5. Result of essential element concentrations in lyophilized commercial baby food samples

Sample	Concentration (on dry weight)							
	Na (%)	K (%)	Fe (µg/g)	Zn (µg/g)	Ca (µg/g)	Co (ng/g)	Cr (ng/g)	Cs (ng/g)
PCL	0.303±0.015	1.144±0.084	30.4±2.2	58.2±3.9	586±63	113.7±6.9	322±47	156±7
PFL	0.316±0.039	1.107±0.069	24.4±2.7	14.7±0.8	527±6	86±14	12±5	73.0±0.4
PFM	0.340±0.026	1.11±0.13	19.6±1.5	13.9±1.2	416±118	<LD	219±14	33.09±0.02
PCG	0.283±0.098	1.19±0.21	28.7±2.1	61.7±3.1	610±13	39.3±2.1	<LD	101.1±4.2
PHFA	0.308±0.032	1.107±0.085	21.7±1.6	38.2±5.6	1260±73	72.7±9.4	318±72	26.2±1.3
PLM	0.255±0.030	0.969±0.116	19.5±1.4	43.0±2.2	583±22	45.0±8.0	259±8	68.0±2.8
PP	0.310±0.026	0.938±0.058	11.8±1.2	15.7±0.8	649±42	50.0±4.4	253±8	42.5±2.1

All the results obtained are discussed and compared with data previously reported by Khalifa et al and proposed guidelines issued by Anvisa. The concentrations of Ca, Fe, Zn and Cr elements obtained in all seven types of foods analyzed are lower than those reported by Khalifa et al and to the FAO/WHO guidelines. Proper complementary feeding of infants is crucial for their proper development, so low level of essential elements has adverse effects and decrease immunity. The commercial baby foods analyzed do not exceed the upper tolerable limit for any of the minerals or trace elements determined [5, 7].

Table 6. Levels of essential elements concentration *in natura* commercial baby foods samples

Sample	Concentration *in natura* samples							
	Na (mg/kg)	K (mg/kg)	Fe (µg/g)	Zn (µg/g)	Ca (µg/g)	Co (ng/g)	Cr (ng/g)	Cs (ng/g)
PCL	474 (826)[a]	1792	4.76	9.12	91	17.8	50.4	24.4
PFL	600 (939)[a]	2100	4.63	2.79	99	16.3	22.9	13.8
PFM	672 (696)[a]	2191	3.88	2.75	82	<LD	43.3	6.54
PCG	478 (817)[a]	2013	4.85	10.4	103	6.64	<LD	17.1
PHFA	573 (775)[a]	1982	4.03	7.10	234	13.5	59.1	4.87
PLM	498 (739)[a]	1891	3.80	8.39	114	8.78	50.5	13.3
PP	570 (730)[a]	1724	2.17	2.89	119	9.19	46.9	7.81
WHO	**-**	**-**	**9[b]**	**4.1[b]**	**400[b]**	**-**	**5.5[b]**	**-**

[a]Values in parenthesis indicate values informed on the label <LD: limit of detection
[b] WHO- Recommended daily intake. Values in mg/day

The problem of iron deficiency anemia is much higher in developing countries where iron-fortified food is less available than in industrialized countries. A WHO/UNICEF review of complementary feeding in developing countries also recognized that iron and zinc requirements may be difficult to meet from non-fortified complementary foods [3].

Zinc deficiency can occur associated to insufficient intake or low bioavailability of this mineral in diets, having been observed in communities by various authors. Infants do not posses zinc reserves, depending immediately, therefore, on the diet sources of this element. This mineral, furthermore, is much better absorbed when originating from human milk than from baby formulas or other kind of food. Zinc deficiency can harm growth and compromise the immune function, besides causing reversible hypogonadism [4].

As can be observed from the results obtained that commercial baby foods do not meet the daily intake requirements of these nutrients. Therefore these results should be taken into account for the safe and healthy nutritional development of the baby. In view of the above it is important that child continue to be breastfeed or be feed with infant formula together with complementary baby food.

4. CONCLUSIONS

The results of this study showed that the most essential element levels in different commercial baby foods samples marketed in São Paulo city were lower that the WHO recommendations. These preliminary data encourage further study for determine other essential elements in a variety of commercial baby foods available in the markets of São Paulo city

ACKNOWLEDGMENTS

The authors thank CNEN, CNPq and CAPES for financially supporting this study.

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