Food Chemistry Advances 1 (2022) 100039

Contents lists available at ScienceDirect

Food Chemistry Advances

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

Estimation of daily dietary intake of essential minerals and trace elements in commercial complementary foods marketed in Brazil

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A R T I C L E I N F O

Keywords:
Daily dietary intake
Commercial complementary food
Essential mineral
Trace element, INAA

A B S T R A C T

Eating habits influence health and development throughout life and commercial complementary foods are an important part of the diet for many infants. In this study, Ca, Fe, K, Mn, Mg, Na, Se and Zn were determined in twenty-seven Brazilian commercial complementary foods samples by Instrumental Neutron Activation Analysis. Daily dietary intakes of the elements were estimated in three groups aged 6–8 months, 9–11 months and 12–24 months from breastfed and non-breastfed infants and young children. Non-breastfed children presented higher daily dietary intakes for all elements. Daily dietary intakes of Fe, Mg, Mn, Na and Zn did not meet the recommended values for the 6–8 and 9–11 months for the breastfeeding group. Ca, K, Mg, Mn, Na and Zn dietary intakes were below the recommended values for 12–24 months for breastfeeding group. Se daily dietary intakes were inadequate in all studied groups. No investigated element exceeded the upper limits. It was observed that the commercial infant food analyzed do not provide sufficient amount of essential minerals and trace elements for the child healthy development in accordance to the international health recommendations.

1. Introduction

Human milk is recognized as the most complete and suitable food for the healthy growth and development of infants and young children. The World Health Organization (WHO) recommends that breastfeeding should be initiated within the first hour after birth and that infants should exclusively breastfeed until they complete six months of age. After this age, WHO recommends the introduction of complementary foods and maintenance of breastfeeding up to two years old (World Health Organization, 2018).

Complementary feeding, as defined in 2002 by WHO, is "the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants" so that "other foods and liquids are needed, along with breast milk" (World Health Organization - WHO, 1981; Fewtrell et al., 2017). Complementary feeding has become a concern due to its importance in healthy growth and development of children as well as its long-term effects in the health of adults.

Complementary feeding generally takes place between the 6–24 months of life and constitutes an increasing part of the infant dietary intake. After six months of age, complementary foods become essential in the baby´s development as these foods are responsible for additional provision of energy, proteins, vitamins, and minerals. Breastfeeding should be continued even after the introduction of complementary foods, since it provides proteins with high biological value and supplies the energy needs of infants. The correct feeding of infants and young children with complementary foods is important for their good nutrition and development and allows the transition to normal foods (Lind et al., 2019; Padarath et al., 2020).

The eating habits of the population have changed a lot in recent years. Studies have shown that commercial complementary infant foods contribute significantly to infant dietary intakes (Maslin & Venter, 2017; Katiforis et al., 2021). Parental education (lower education level), maternal employment and maternal smoking history were associated with increased daily intakes from commercial complementary foods (Theurich et al., 2020). A problem of the exclusive use of commercial infant foods as the only source of complementary food is the little or no variety within the meal. Another concern is the lack of information on the label in these foods. Then, it is important to know about the content of foods, especially when they are intended for infants and young children. In Brazil, the National Health Surveillance Agency (ANVISA) determines nutritional information to be displayed on food labels, but the only element whose concentration must be informed is sodium (Brasil, 2003).

Data on the contents of essential mineral and trace elements in commercial complementary foods consumed by the Brazilian population are scarce. The objective of this study was to determine the contents of Ca, Fe, K, Mg, Mn, Na, Se and Zn in commercial complementary foods by Instrumental Neutron Activation Analysis (INAA) and to estimate their

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https://doi.org/10.1016/j.focha.2022.100039
Received 24 November 2021; Received in revised form 25 April 2022; Accepted 26 April 2022

Table 1
Types of commercial complementary foods acquired in the Brazilian market.

Commercial complementary foods	Type of meal	Age recommendation
Stage 1	One fruit	Older than 6 months
Stage 2	2 fruits or fruit/milk	Older than 6 months
Stage 2	Porridge of different foods including meat and vegetables	Older than 6 months
Stage 3	Porridge/Meal of different foods including meat and vegetables	Older than 8 months
Junior Stage	Meal	Older than 12 months

daily dietary intakes, in order to verify if the recommended daily dietary intakes are achieved.

2. Materials and methods

2.1. Description of the commercial complementary foods

The commercial complementary foods analyzed in this study are from the one brand available at São Paulo city, Brazil, at the time of sampling, as presented in Table 1. These products are classified into four different stages by the producer, according to child age, composition, flavors, and textures. Stage 1 can be offered as porridge to babies after six months and allows that babies discover the food. Thus, these foods are composed by only one type of fruit. Stages 1 and 2 are adequate for babies other than 6 months, but new flavors and foods are introduced in Stage 2. Stage 3 is offered to 8-month-old babies and these foods will be responsible to stimulate the babies to chew. So, in the third stage some constituents are in pieces, not only in the form of a porridge. Finally, the last stage, called Junior Stage, is designed to provide nutrition for children growth and development as well as their adaptation to normal diets. Therefore, foods present flavors similar to those offered during family meals.

2.2. Sample preparation

Twenty-seven commercial complementary foods of the 1, 2, 3 and Junior Stages were analyzed. Commercial complementary food samples were coded and transferred from their containers to polyethylene vials, previously cleaned with deionized H_2O and 10% (v/v) HNO_3 solution. The samples were then stored in a refrigerator at -4 °C to maintain the product in adequate conditions.

Samples were freeze-dried during 15 h in a Modulyo D freeze-dryer (Thermo-Electron Corporation) at -51°C and 49 μbar. After the lyophilization process, samples were grounded and homogenized in a domestic blender, which was adapted with titanium blades. The percentages of water weight loss during this process varied from 79% to 88%. Table 2 describes the commercial complementary food samples analyzed in this study.

Table 2
Compositions of the commercial complementary food samples analyzed in this study.

Stage	Sample code	Composition
1	1-a	Plum
1	2-a	Cashew apple
1	3-a	Apple
1	4-a	Passion fruit
1	5-a	Grapes
2	1-b	Banana with milk
2	2-b	Guava with milk
2	3-b	Assorted fruits
2	4-b	Tropical fruits
2	5-b	Apple and banana
2	6-b	Mango with pear
2	7-b	Peach with milk
2	1-c	Meat with vegetables
2	2-c	Bean soup with vegetables and beets
2	3-c	Chicken with vegetables and noodles
2	4-c	Egg yolk with meat and vegetables
2	5-c	Vegetables with chicken breasts
2	6-c	Meat with vegetables and parsnip
2	7-c	Turkey breasts with vegetables and rice
3	1-d	Bean soup, meat and rice
3	2-d	Vegetables and meat
3	3-d	Chicken breasts with vegetables
3	4-d	Noodles, meat and vegetables
Junior	1-e	Spaghetti Bolognese
Junior	2-e	Chicken risotto
Junior	3-e	Mince
Junior	4-e	Stroganoff with rice

2.3. Preparation of standards

Standards of Ca, Fe, K, Mg, Mn, Na, Se 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 papers and dried under infrared lamp. After drying, these filter papers were placed into clean polyethylene bags.

2.4. Element determination by INAA

Two irradiation protocols were used for element determination by INAA, depending on the half-lives of the analytical radionuclides. About 0.1 g of freeze-dried commercial complementary food samples weighed in polyethylene bags were irradiated together with element standards and certified reference materials for 20 s under a thermal neutron flux of 6.6×10^{12} cm^{-2} s^{-1} at the IEA-R1 nuclear research reactor of Nuclear and Energy Research Institute (IPEN-CNEN). The elements K, Mg, Mn and Na were determined using this irradiation condition. About 0.2 g of freeze-dried commercial complementary food samples weighed in polyethylene bags were irradiated together with element standards and certified reference materials for 8 h under a thermal neutron flux of 4.5×10^{12} cm^{-2} s^{-1} at the IEA-R1 nuclear research reactor of IPEN-CNEN. In this irradiation condition, the elements Ca, Fe, Se and Zn were determined. Gamma-ray activities were measured with a POP TOP model High Purity Ge detector from EG&G ORTEC with 20% efficiency and 1.9 keV resolution at 1332 keV photopeak of ^{60}Co. The detector is coupled to an electronic system composed of multichannel analyzer, source of high tension, amplifier and a compatible microcomputer. Gamma-ray spectra were analyzed using the VISPECT2 software. The following analytical radionuclides and gamma ray photopeaks were used: ^{47}Ca (1297 keV), ^{59}Fe (1099 keV), ^{42}K (1524 keV), ^{27}Mg (843 keV), ^{56}Mn (846 keV), ^{24}Na (1368 keV), ^{75}Se (265 keV) and ^{65}Zn (1115 keV) (Kira & Maihara, 2007).

2.5. Element daily dietary intakes

The daily dietary intakes of essential minerals and trace elements were estimated following the feeding guideline for children by the Brazilian Pediatric Society (Departamento de Nutrologia da Sociedade Brasileira de Pediatria, 2018). According to the guideline, the introduction of complementary foods to children's diet should be started after 6 months of age, with the highlights that they should be natural and healthy and that for older children, foods should be the same as those for the family. Complementary food should be offered three times a day if

Table 3
Element concentrations (mean ± SD, $n = 8$), relative standard deviation (RSD, %) and relative error (RE, %) obtained for the certified reference materials by INAA.

Element	INCT-MPH-2 Mixed Polish Herbs				NIST 1577b Bovine Liver			
	This study	RSD (%)	RE (%)	Certified value[a]	This study	RSD (%)	RE (%)	Certified value
Ca µg/g	10842±241	2.2	0.39	10800±700	< 120[b]	-	-	116±4
Fe µg/g	487±36	7.4	5.9	(460)	185.2±8.2	4.4	0.54	184±15
K µg/g	19176±1083	5.6	0.40	19100±1200	9486±764	8.1	4.8	9940±20
Mg µg/g	2944±68	2.3	0.82	2920±180	575±52	8.9	4.5	601±28
Mn ng/g	188.1±9.7	5.2	1.5	191±12	10.28±0.89	8.7	2.2	10.5±1.7
Na µg/g	346.7±7.0	2.0	0.94	(350)	2217±136	6.1	9.2	2420±60
Se ng/g	ND[c,d]	-	-	-[d]	728±25	3.4	0.27	730±60
Zn µg/g	33.3±1.6	4.8	0.60	33.5±2.1	128.4±8.2	6.4	0.79	127±16

[a] Parentheses indicate informative values
[b] below limit of detection
[c] not determined
[d] not certified

the child receives human milk, and five times a day for weaned children. Zand et al. (2011) affirmed that it is important to consider the entire daily intake when studying the nutrient quality of complementary foods, then breast milk or infant formula must also be considered. Hence, in this study, for the estimation of the daily dietary intakes for children fed with commercial complementary foods, we considered 3 daily food pot servings (1 fruit and 2 porridges or meal) and variable amounts of full-term mature human milk for breastfed children and 4 meals (2 fruits and 2 porridges or meal) and variable amounts of follow-on infant formula for non-breastfed children. According to Kent et al. (2006), despite the large standard deviation, the variation in breast milk production is related to the variation in infant growth rates: for infants 1 to 6 months of age the overall 24-h human milk production was 788 ± 169 mL. Using the available literature, other studies assumed an average intake of the 780 mL for infants aged 0–5.9 months, 600 mL for infants aged 6 to 11.9 months and 89 mL for young children with 12–17.9 months of age (Butte et al., 2010; Eldridge et al., 2019). In this study, we adopted the milk and infant formula volumes of these two authors to estimate the daily dietary intake for breastfeeding and no-breastfeeding infants and young children.

For the element concentrations in breast milk and infant formula, we used the values obtained from studies conducted in Brazil. Mastroeni et al. (2006) studied the levels of Ca, K, Mg, Fe, P and Zn in colostrum and mature maternal milk from 43 healthy Brazilian mothers and the correlations between the level of the element concentrations and newborn weight, maternal age, gestational age, and gestational weight gain. Peixoto et al. (2019) determined Ba, Cu, Fe, Mn, Mo, Se, Sr and Zn in preterm and term human milk to verify the differences about preterm and term human milk and its processing in a human milk bank. Santos (2009) determined essential elements in three types of infant formula commercialized in São Paulo city: formulas for high-risk newborns, for therapeutic needs and for follow-up. Concentrations of Ca, Fe, K, Mg, Na and Zn in mature human milk from Mastroeni et al. (2006); Mn and Se concentrations in term human milk from Peixoto et al. (2019) and in follow-up infant formula samples from Santos (2009) were considered in the calculation of the daily dietary intakes.

3. Result and discussion

3.1. Quality control

To assess the accuracy of the method, two certified reference materials (CRMs), INCT MPH-2 Mixed Polish Herbs and NIST SRM 1577b Bovine Liver were simultaneously analyzed with the samples. Table 3 presents the obtained results and certified values. The results agreed with the certified values, resulting in adequate accuracy (relative standard deviation < 8.9%; relative error < 9.2%).

3.2. Element determination in commercial complementary foods

INAA was applied to determine Ca, Fe, K, Mg, Mn, Na, Se and Zn in twenty-seven commercial complementary food samples representing various products of only one brand. The commercial complementary food products were divided in four groups according to the age recommendation, type of food and textures.

Table 4 shows the masses of the essential elements determined in the commercial complementary foods commercialized in São Paulo city analyzed by INAA per 100 g of *in natura* sample. Table 5 shows the amounts of elements present in each food pot, the mean element mass values per pot of different stages and element concentrations in human milk and infant formula.

3.3. Daily dietary intakes

Daily dietary intakes were estimated from the values on Table 5 for three age groups: 6–8 months, 9–11 months and 12–24 months to breastfed and non-breastfed infants and young children, following the rationale described in item 2.5 of Materials and Methods. Estimated daily dietary intakes are presented in Table 6, with values for the Dietary Reference Intakes (DRI) for Ca, Fe, K, Mg, Mn, Na, Se and Zn and Upper Limits (UL) for Ca, Mg, Mn, Fe, Se and Zn. UL is the maximum level of daily element that is likely to pose no risk of adverse effects (IOM, 2019).

Regarding the element content on labels of infant food products, only Na content is mandatory (Brazil, 2003). Dairy products also present Ca levels on the labels. The Na and Ca concentrations obtained in all commercial complementary foods agreed with those reported on the food labels.

Calcium is required for the normal development and maintenance of the skeleton as wells as for proper functioning of neuromuscular and cardiac systems. In childhood, it is required for proper bone mineralization and growth. Ca is predominantly obtained from milk and milk-based products (Cormick & Belizán, 2019). In the analyzed commercial complementary foods, Ca content varied from 4.9±0.3 mg/100g (cashew apple) to 158±16 mg/100g (peach with milk). The quantity of Ca in foods containing meat and chicken is greater than in fruits, except when milk was part of composition. As expected, fruits with milk presented the large amount of Ca (121±11 to 158±16 mg/100g) in comparison with the other samples, as observed in Table 4. Samples from Junior stage (mince and stroganoff with rice) also presented high level of Ca (435±40 and 678±67 mg/kg). Although milk does not appear as the main ingredient, its presence is indicated on the label in the category of ingredients in both samples. These values are in accordance with data reported by Zand et al. (2011), ranging from 15 to 192 mg/100g in commercial poultry and fish infant products commercialized from the United Kingdom markets and were lower than the ones reported by Melo et al. (2008) from 10.3 to 738 mg/100g in

Table 4
Levels of essential elements in commercial complementary food samples (mean±SD, *n*=3).

Sample[a]	Ca(mg/100g)	K(mg/100g)	Na(mg/100g)	Mg(mg/100g)	Fe(mg/100g)	Zn(mg/100g)	Mn(µg/100g)	Se(µg/100g)
1-a	12.9±1.1	156±13	5.2±0.4	6.1±0.6	0.27±0.03	0.088±0.008	0.089±0.008	0.53±0.06
2-a	4.9±0.3	78±6	3.3±0.3	6.2±0.6	0.17±0.02	0.103±0.009	0.092±0.006	0.34±0.04
3-a	7.4±0.3	83±5	3.3±0.3	2.3±0.2	0.11±0.01	0.044±0.002	0.042±0.004	< 0.20[c]
4-a	6.1±0.6	125±9	3.1±0.2	8.8±0.9	0.14±0.01	0.175±0.003	0.17±0.01	< 0.20
5-a	6.3±0.6	98±7	2.9±0.2	3.8±0.3	0.25±0.02	0.059±0.004	0.083±0.004	0.29±0.03
1-b	121±11	213±14	2.1±0.2	15.4±0.9	0.49±0.05	0.33±0.019	0.24±0.02	0.53±0.05
2-b	131±13	183±10	2.6±0.2	10.5±0.9	0.50±0.05	0.351±0.034	0.125±0.011	0.72± 0.05
3-b	5.3±0.5	95±9	3.3±0.3	4.3±0.4	0.27±0.01	0.051±0.003	0.044±0.004	1.22±0.10
4-b	7.4±0.7	136±11	1.9±0.2	11.4±0.9	0.17±0.02	0.081±0.006	0.534±0.047	1.21±0.11
5-b	8.2±0.4	108±3	4.5±0.4	7.4±0.7	0.20±0.02	0.079±0.003	0.095±0.008	1.01± 0.10
6-b	9.7±0.9	122±11	1.3±0.1	6.4±0.4	0.15±0.01	0.074±0.005	0.105±0.009	< 0.20
7-b	158±16	155±9	21.4±1.9	7.7±0.7	0.39±0.04	0.33±0.03	0.085±0.007	< 0.20
1-c	10.4±1.0	218±13	53.0±4.9	12.4±1.1	0.53±0.04	1.06±0.05	0.069±0.006	1.18±0.10
2-c	8.7±0.8	217±14	62.9±5.1	14.5±1.4	0.49±0.05	0.93±0.09	0.098±0.010	1.80±0.23
3-c	9.9±0.1	234±22	58.4±5.3	11.7±1.1	0.43±0.03	0.27±0.02	0.081±0.008	1.70±0.01
4-c	8.3±0.5	223±6	57.6±5.0	11.1±0.7	0.40±0.04	0.28±0.02	0.0712±0.007	1.74±0.17
5-c	23±2	201±17	55.4±5.1	14.9±1.3	0.40±0.04	0.64±0.04	0.232±0.019	2.07±0.10
6-c	11.2±0.7	193±7	57.6±5.3	9.6±0.9	0.40±0.04	0.78±0.07	0.059±0.006	2.56±0.17
7-c	12.9±1.2	176±10	58.8±5.3	10.8±1.0	0.21±0.02	0.29±0.01	0.071±0.007	8.00±0.51
1-d	17.2±1.3	218±21	86.1±7.9	16.0±0.9	0.74±0.06	0.22±0.02	0.133±0.013	1.85±0.10
2-d	9.1±0.5	278±25	95.9±5.3	12.5±0.9	0.54±0.05	0.77±0.04	0.110±0.009	1.12±0.09
3-d	11.1±0.9	217±20	94.5±4.7	12.3±1.2	0.33±0.03	0.29±0.02	0.062±0.050	1.98±0.10
4-d	9.8±0.8	188±17	84.5±5.0	9.6±0.9	0.60±0.05	0.90±0.05	0.082±0.007	0.84±0.04
1-e	9.2±0.8	275±24	102±8	7.4±0.2	2.67±0.19	0.90±0.04	0.094±0.008	0.47±0.04
2-e	9.9±1.0	354±19	134±12	18.2±1.0	2.72±0.23	0.97±0.08	0.090±0.008	0.98±0.09
3-e	44±4	265±25	163±13	12.5±0.3	2.22±0.22	0.34±0.03	0.085±0.006	1.77±0.17
4-e	68±7	365±19	137±11	10.9±0.8	2.90±0.24	0.88±0.08	0.085±0.006	2.29±0.11

[a] (a): Stage 1, fruits; (b) Stage 2, fruits; (c) Stage 2, porridge; (d) Stage 3 – porridge; (e) Junior Stage, meal
[c] below detection limit

Table 5
Element mass per pot of different stages (mean±SD) and the values of human milk and follow-up infant formula concentrations.

Element	Fruits 6-24 months	Porridge 6-8 months	Porridge 9-11 months	Meal 12-24 months	Maternal human milk	Follow-up Infant Formula
Portion size (g)	120	115	170	250	unit/L	unit/L
Ca mg	47.9±71.0	13.8±6.0	20±6	82±71	250±31	583±120
K mg	155±50	240±23	383±64	787±130	462±84	586±100
Na mg	9.7±11	66±4	153±10	335±63	205±156	168±123
Mg mg	9.1±4.3	14±2	21.4±4.0	31±11	29.9±5.0	53.12±15
Fe mg	0.31±0.16	0.47±0.13	0.91±0.26	6.57±0.72	0.9±0.5	8.04±1.08
Zn mg	0.18±0.15	0.70±0.38	0.92±0.58	1.94±0.73	0.15±0.06	6.03±0.40
Mn µg	171±162	112±69	164±53	221±11	5.5	57.35±27
Se µg	1.0±0.4	1.9±1.0	2.5±1.0	3.4±2.0	8.4	10.6±3.3

Maternal human milk: Mean ±SD of Ca, K, Na, Mg, Fe and Zn from Mastroeni et al. (2006); Median of Mn and Se from Peixoto et al. (2019)
Follow-up infant formula: Mean ±SD of the elements from Santos (2009)

Table 6
Daily dietary intakes for different child groups for Ca, K, Na, Mg, Fe, Zn (mg/day) and Mn and Se (µg/day) and corresponding Dietary Reference Intakes (DRI) and Upper Limits (UL).

Element	Nourishment	Age group			DRI		UL	
		6–8 months	9–11 months	12–24 months	7–12 months	1–3 years	7–12 months	1–3 years
Ca	Breastfed	305	266	200	260	700	1500	2500
	non-breastfed	578	486	312				
K	Breastfed	910	971	1139	860	2000	ND	ND
	non-breastfed	1217	1428	1936				
Na	Breastfed	247	296	372	370	800	ND	ND
	non-breastfed	282	426	704				
Mg	Breastfed	56	57	51	75	80	ND	65
	non-breastfed	88	93	85				
Fe	Breastfed	1.8	2.1	7.3	11	7	40	40
	non-breastfed	7.9	7.3	14.5				
Zn	Breastfed	2.2	2.2	2.4	3	3	5	7
	non-breastfed	6.5	5.8	4.8				
Mn	Breastfed	458	509	564	600	1200	ND	2000
	non-breastfed	611	704	789				
Se	Breastfed	10.4	9.4	6.1	20	20	60	90
	non-breastfed	13.9	13.2	9.7				

ND: Not determined

Spanish commercial baby food. Appropriate dietary intake of Ca, vitamin D and other important nutrients is fundamental for the maintenance of skeletal health. In this study, the Ca dietary intakes met the recommended values whose intake values obtained were 305 mg/day and 266 mg/day for 6–8 month and 9–11 month for breastfed; 578 mg/day and 486 mg/day for 6–8 month and for 9–11 months for no-breastfed infants (Table 6). These values were smaller than reported by Sharma et al (2013) 711.5 mg/day for 7–12 months and 610.9 mg/day for 13–24 months, Melo et al (2008) 864 mg/day for 6–12 months and by Zand et al (2012) 417 mg/day. However, due to the low consumption of breastmilk and infant formula in the 12-24 months of age (89 mL), calculated ingestion values were also low for this age group, resulting in inadequacy of Ca intake for both infant groups. It is important emphasize the importance of consuming adequate amounts of food sources of Ca since inadequate dietaries of Ca (in association with vitamin D) may lead to weakening of bones that leads to the clinical manifestations of rickets and osteomalacia (Uday & Högler, 2018).

Potassium is an essential mineral that the body needs for the maintenance of total body fluid volume, acid and electrolyte balances, and normal cell functions. Foods that contain K can help managing blood pressure by reducing the negative impact of sodium (Aburto et al., 2013). In the present study, potassium contents were smaller in fruit samples, except the samples 1b (213 mg/100g in banana with milk) and 2b (183 mg/100g in guavas with milk). These fruits are considered sources of this element. Porridges and meals presented at least one source of this element, such as potatoes, milk, green vegetables, legumes, and whole grain products. Another possibility for the high K content is the use of light salt. In light salt, part of the sodium chloride is replaced by potassium chloride, leading to a lower sodium chloride concentration than ordinary table salt (Zand et al., 2011). The daily dietary intakes obtained varied from 910 to 1936 mg/day. The recommended values of daily ingestion for K were reached for breastfeeding and non-breastfeeding infant groups, except for the 12–24 years old for both groups. In other studies, the K dietary intakes were similar: 1831 mg/day for 6–12 months (Melo et al., 2008), 800 mg/day for 6–9 months (Zand et al., 2012) and 1045 mg/day for 0–24 months (Sharma et al, 2013). In children of 2–5 years of age, increased K intake reduced systolic blood pressure by a small, non-significant amount. Higher K intake was associated with a reduced risk of incident stroke (Aburto et al., 2013). High consumption of K from foods is safe as the human body is able to excrete excess K via the urine. Due to this safety, no upper limit for K has been considered (IOM, 2019).

Sodium is the principal cation in extracellular fluid in the body and is an essential mineral necessary for maintenance of plasma volume, acid–base balance, transmission of nerve impulses and normal cell function (World Health Organization- WHO, 2012a). Sodium is found naturally in a variety of foods, such as milk, meat and shellfish, in addition with chloride, being the component of common table salt. A diet high in processed foods and low in fresh fruits and vegetables is often high in sodium. In the studied commercial infant foods, as expected, porridge and meals which present vegetables, meat and chicken have a more expressive amount of Na compared to fruit samples, suggesting table salt as the probable main source of this element. The amount of Na also increased with the progression of the stages. The obtained dietary intake values for Na (282 to 704 mg/day) were below the recommended reference values, except for the 9–11-month age, no-breastfeeding group. Zand et al. (2012) reported value of 214 mg/day for 6–9 months and Sharma et al (2013) obtained higher values of 794 mg/day for 7–12 months and 1627.2 mg/day for 13–24 months. No value of UL for Na for infants and young children age has been determined due to a lack of data of specific toxicological adverse effects (IOM, 2019).

Magnesium is an essential mineral that is involved in a wide range of vital biologic processes. The human body requires a continuous supply of Mg dietary intake for correct development of its metabolic functions (Veronese et al., 2017; Rosique-Esteban et al., 2018). Mg plays a key role in bone and in the growing child. It is essential to maintain a positive Mg balance so that the amount of this element needed for growth and metabolic needs is ensured (Ledeganck et al., 2018). Nuts, seeds, whole grains, leafy vegetables and cereals are sources of Mg. In the commercial complementary foods, the quantity of Mg varied from 2.3±0.2 (apple) to 18.2±1.0 mg/100g (chicken risotto). These values were lower than the obtained by Zand et al. (15 to 49 mg/100g) and by Melo et al. (8.21 to 93.8 mg/100g). The great variability of Mg found in almost all samples can be attributed to the use of fertilizers in the farms producing the used vegetables. None of the children fed with human milk (51 to 57 mg/day) met the recommendation values (75–80 mg/day), but these values were obtained for children fed with infant formulas (85–93 mg/day). Most infant formulas have higher Mg content than what is found in human milk (Mandiá et al., 2021). In the literature similar values were reported: 90 mg/day for 6-9 months (Zand et al., 2012) and 108.9 mg/day for 7–12 months (Sharma et al, 2013). Deficiency of Mg in human is rare, unless low intakes are accompanied by prolonged diarrhea or excessive urinary loss (Ledeganck et al., 2018). For 1–3 year-age group, the UL appears to be lower than the DRI. This occurs because the DRI includes Mg from all sources (food, beverages, dietary supplements, and medications). The UL value includes Mg from only dietary supplements and medications and do not include Mg found naturally in food and beverages (National Institute of Health (NIH), 2021).

Iron concentration present in the foods *in natura* varied from 0.11±0.01 (apple) to 2.90±0.24 mg/100g (stroganoff with rice). The values obtained were smaller than the results reported by Melo et al. (2008), ranging from 0.10 to 11.1 mg/100g, but similar to Zand et al. (2011) (0.5 to 3 mg/100g). The Fe content in Junior Stage meals was much higher than in the other stages because meat is the principal ingredient, and it is the best source of this element. Iron deficiency is the most common world nutritional deficiency, and it is considered a major cause of anemia, particularly during infant and early childhood and the requirement during the weaning period is high (World Health Organization - WHO, 2012b; Khan et al., 2014). The prevalence of anemia among less than 4 years of age is between 46% and 66% in developing countries. The Brazilian Health Ministry supported the National Child Food and Nutrition Study (ENANI-2019) to evaluate the practices of breastfeeding and feeding, anthropometric nutritional status and micronutrient deficiencies among Brazilian children under 5 years old. The prevalence of anemia in Brazil was 19 % for infants 6–23 months of age and 5.6% for 24–59 months (Universidade Federal do Rio de Janeiro (UFRJ), 2019). The critical period is concentrated between 6 months and 2 years. Breast milk is low in Fe and supplement is recommended after the age of 4 months (Eldridge et al., 2019). High Fe levels in infant formula have been justified by low Fe bioavailability as well as the concern on Fe deficiency in infants (Ljung et al., 2011). Usually, infant formulae are fortified with Fe. For this reason, Fe dietary intakes in breastfed children are lower than intakes for children feeding with infant formula. The estimated Fe daily intake values (1.8 and 2.1 mg) for 6–8 and 9–11 months were exceptionally lower than the DRI value (11 mg) which implies that mainly breastfed children, fed by commercial foods composed only by fruits and vegetables can have their health development impaired. Although porridge for the children up to 8 months age have meat in their composition, the amount is not enough to provide a sufficient Fe intake. Obtained values were similar to those of Spanish infants at 4, 6, 8 and 12 months that ranged from 1.1 to 3.3 mg/day for breastfed children fed with infant cereals with gluten or diets with gluten-free rice (Carbonell-Barrachina et al., 2012). Deficiency of Fe was also observed by Mir-Marqués et al. (2015) in their study about Spanish baby food whose values were very low, circa 5–20% of recommended values. Infants over 1 year of age reached the DRI value, due to higher intake of animal protein in the meals, source of this element. Other studies obtained higher values: 10 mg/day (Zand et al., 2012) and 21.1 mg/day for 7-12 months and 8.2 mg/day for 13–24 months (Sharma et al., 2013). The benefit of Fe fortification in the first years of children is unquestionable for healthy development throughout life. However, several studies have shown adverse effects of excessive iron exposure. These effects include decreased growth, impaired cognitive and motor development, impaired of Zn and Cu absorption (Lönnerdal, 2017; Wessling-Resnick, 2017). The estimate dietary Fe intake value was twice the DRI value for 1–3 years no-breastfed children, although it is far from the UL value of 40 μg/day.

Zinc is one of the most important trace elements of great public health significance. Zinc is extensively involved in the normal function of the immune system, wound repair, and blood pressure regulation. It plays essential roles in learning and memory. In infants and children, the main causes of Zn deficiency are parenteral nutrition, undernourishment, malnutrition or low Zn levels in breast milk (Chasapis et al., 2020). The amount of Zn present in the analyzed samples varied from 0.044±0.002 (apple) to 1.06±0.05 mg/100g (meat with vegetables). It is possible to verify a greater amount of this nutrient in the salty samples, mainly in the samples of the Junior Stage. The fruit samples presented lesser amounts of Zn, but it is possible to observe that among them, 1b (banana with milk), 2b (guava with milk) and 7b (peach with milk) samples had a greater amount of this element than the others. This is because these samples contain milk in their composition, which is considered an important source of Zn (Sanches et at., 2020). The estimated Zn dietary daily intakes were adequate only for infants fed with commercial food and infant formula. The daily intake of Zn represented circa of 73 to 80% of the DRI value for breastfed infants and young children. In the 6–8 and 9–11 months of no-breastfeed groups the estimate dietary daily intake values were higher than the UL value. In a United States study, the mean intakes of Zn by children aged bellow 1 y, 1–3 y, and 4–5 y were 6.6, 7.6, and 9.1 mg/d, respectively. According to the authors, these intake levels do not seem to pose a health problem as Zn has relatively low toxicity compared to other trace elements (Arsenault & Brown, 2003). The efficiency of its excretion into bile and intestinal secretions may help protect against toxicity (Livingstone, 2015).

Manganese is a trace element involved in diverse functions, such as metabolism of carbohydrate, cholesterol, amino acids and formation of bone. In recent years, an increasing number of researchers have been investigating how Mn is potentially beneficial for cardio metabolic health (Wong et al., 2022). There are many sources of Mn, so there was a great variation in the amount of this element among the analyzed samples that varied from 0.044±0.004 (assorted fruits) to 0.534±0.047 mg/100g (tropical fruits). Similar to Fe, many infant formulae are fortified with Mn, although deficiency is virtually unknown in humans and evidence of its toxicity is growing (Ljung et al., 2011). The increased exposure of infants to Mn may be associated with adverse neurotoxic effects and Fe deficiency can increase Mn toxicity (Misic et al., 2022). The dietary intake values for Mn met the DRI values for two age groups

(611 μg/day for 6–8 months and 704 μg/day for 9–11 months) in non-breastfed infant groups. Smaller values were obtained by Zand et al. (2012): 35 μg/day and by Škrbić et al. (2017): 33.7 μg/day for 7–12 months.

Selenium is an important trace element, and it takes part of 25 selenoproteins which some important biological functions, playing a role of protection on oxidative processes, in thyroid hormone metabolism and overall modulation of growth and development (Ibrahim et al., 2019). Selenium deficiency has been associated with a number of diseases and clinical complications, such as increased risk of respiratory diseases, myocardial disorders, skeletal muscle disorders, erythrocyte macrocytosis and growth retardation (Avery & Hoffmann, 2018). In the analyzed commercial complementary foods, Se amounts were quite variable among the samples (<0.20 to 8.00±0.51 μg/100g). In some foods, Se concentrations were below its detection limit. It was possible to verify that the salty samples contain a greater amount of this element than the sweet samples. This may be related to the meat present in these samples, considered a source of this element. Of all the nutritional elements, Se has one of the narrowest intervals between dietary deficiency and toxic level, which demands careful control of its intake (Fordyce, 2013). The need to ingest this element is very close to its Upper Limit (UL). Hence, depending on the amount of Se ingested, symptoms of deficiency as well as toxicity can be observed (Cominetti et al., 2011). The 20 μg/day DRI value for this element was not reached by any group. Of course, all groups were distant from the UL level, and there is no need to worry about the toxicity of this element in relation to commercial complementary foods (IOM, 2001).

4. Conclusions

The contents of the investigated essential minerals and trace elements in the commercial complementary foods varied markedly between the different food types. Essential element daily dietary intakes estimated from commercial complementary foods for breastfed infants were lower than the intakes for non-breastfed infants. Despite these findings, breastfeeding is highly recommended as human milk is an essential source of other nutrients and bioactive factors. Fe daily dietary intake was particularly low in breastfed infant diets from 6 to 11 months old, which can lead to development impairment. For 12–24 months no evaluated diet was sufficient for both infant groups, except for Fe and Zn for the non-breastfed group. For 6–8 and 9–11 months of age only Ca and K for both infant groups, while Mg, Zn and Mn for non-breastfed group met the DRI values. No studied ages and diet groups reached the recommended values for Se daily dietary intake, suggesting Se supplementation on infant food is recommendable, but always considering the UL and its toxicity. No investigated element exceeded the upper limits. In this study, it was observed that the commercial infant food analyzed do not provide sufficient amount of essential minerals and trace elements for the child healthy development in accordance to the international health recommendations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Priscila Vallinoto: Validation, Investigation, Writing – original draft. **Edson G. Moreira:** Writing – review & editing. **Vera A. Maihara:** Conceptualization, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Acknowledgments

Authors thank to the Brazilian National Energy Commission (CNEN) and the Brazilian National Council for Scientific and Technological Development (CNPq) for fellowships (CNEN – BMT modality and CNPq Process 302896/2005-5) and for financially supporting this study.

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