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ORIGINAL PAPER

THE CONTENT OF MAGNESIUM, CALCIUM, SODIUM AND POTASSIUM IN INFANT FORMULAS

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Abstract

Mother's milk is the basic food for infants. Sometimes women for various reasons cannot continue or are not willing to continue breastfeeding their babies and then infant formula provides an alternative. Although breast milk substitutes for infants are produced using high technology methods, their composition is to some extent different than that of breast milk. Breast milk does not contain a high amount of minerals on the overall (ash accounts for circa 0.2 %) but they are characterised by a very high level of assimilability. On the other hand, cow's milk contains much higher amounts of minerals – ca. 0.7%. Cow's milk contains 3 to 4 times more Ca, Mg, Na and K than breast milk. The study aimed to analyse infant and baby formulas in terms of the content of Ca, Mg, Na and K. The study covered 11 infant formulas. All the formulas were annotated as "food for particular nutritional uses". The powdered milk formulas were purchased from retailers in Lublin Voivodeship in August 2014, prior to their best-before dates. The content of Ca, Mg, Na and K was determined by means of flame atomic absorption spectrometry in a Varian SpectrAA 280 FS apparatus. It was found that starter infant formulas contained less of minerals covered by the study than had been declared. It was demonstrated that the content of Ca, Mg, Na and K in the analysed milk samples calculated per 100 kcal was generally comparable to their standard content.

Keywords: infant follow-on formulae, baby, magnesium, calcium, sodium, potassium.

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INTRODUCTION

Milk is the basic nutritive product for infants. As currently recommended, children should be breastfed until the age of two (Gartner et al. 2005, WHO 2001). However, it is not always possible to keep breastfeeding; sometimes women for various reasons cannot continue or are not willing to continue breastfeeding their babies (Arora et al. 2000, Tavetas et al. 2004). Then, an infant or baby formula provides the best alternative. The formula is cow's milk subject to special processing which involves, among other things, changing the proportion between whey and casein protein, replacing animal fat with vegetable fat, reducing the content of sodium and enriching the milk with necessary micro- and macroelements (Zagórecka et al. 2007). Thanks to such processing the composition of the formula is similar to that of breast milk and thus it is as closely as possible adapted to the needs of the infant, satisfying all development-related needs.

Although breast milk substitutes for infants are produced using high technology methods, their composition is to some extent different than that of breast milk; e.g. breast milk does not contain a high amount of minerals on the overall (ash accounts for circa 0.2%) but they are characterised by a very high level of assimilability (Foda et al. 2004, Soliman 2005). On the other hand, cow's milk contains much higher amounts of minerals – ca. 0.7% (Soliman 2005). Cow's milk contains 3 to 4 times more calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) than breast milk (Stolarczyk 2001, Soliman 2005). These macroelements are responsible for the correct functions of an intensively developing organism such as correct mineralisation of bones and teeth and muscle contraction (Ca, Mg), nerve impulses and activation of numerous enzymatic changes (Mg, K), energy changes (Mg), maintaining osmotic and acid-base balance (Na) and the blood-forming processes (Mg) (Krebs 2001, Lynch, Stoltzfus 2003, Shimoni 2005, Griffin et al. 2008, Soetan et al. 2010, Zych et al. 2011, Winiarska-Mieczan 2014).

Infants and babies are particularly sensitive to both excess and deficiency of minerals, thus foods for particular nutritional uses designed for such consumers must contain a sufficient amount of components to cover the requirement. Breast milk changes its composition as the infant grows older and the content of its components is always adequate thanks to physiology; however, the content of minerals in the infant formula must be constantly adapted to the baby's age by changing the recipe. The study aimed to investigate whether the infant and baby formulas available in the Lublin market contain Ca, Mg, Na and K in amounts covering the requirement characteristic of this group of consumers. In addition, it was analysed whether the actual amount of Ca, Ma, Na and K in the studied products was consistent with the values declared by the producer on the packaging.

MATERIAL AND METHODS

Study material

Infant powdered milk formulas for analyses were purchased from retailers in Lublin Voivodeship in August 2014, prior to their best-before dates. A description of 11 products subject to analysis is presented in Table 1.

Chemical analyses

Infant formulas were prepared as instructed by the producer. Afterwards, 3 samples of 5 ml each were taken from each product and dried over 24 h at a temp. of 65°C, and then for a subsequent period of 24 h at a temp. of 103°C. The dried samples were ashed in a muffle furnace at a temp. of 550°C for 16 h. If the sample was not ashed thoroughly (grey ash or ash of non-uniform colour), after cooling, it was mixed with 1 ml of hydrogen peroxide. Then, the reagent was evaporated and the sample was mineralised again at a temp. of 550°C for 12 h. Thoroughly ashed samples (white ash) were dissolved in 10 ml 1M HNO_3. The content of Ca, Mg, Na and K was determined using atomic absorption spectrophotometry in a Varian SpectrAA 280 FS apparatus. The measurement parameters used for determining the content of Mg, Ca, Na and K are presented in Table 2.

Statistical analysis

The content of Ca, Mg, Na and K was presented in mg per 100 ml of the prepared infant and baby formula. The results were analysed by statistical methods. The arithmetic means and standard deviation values (SD) were calculated using Statistica software version 10 (StatSoft, Inc. Statistica 2011). The percentage of coverage of the content of minerals determined in comparison to values declared by the producer was calculated; the declared values were adopted as 100%. With regard to the concentration of energy per 100 ml of the finished product declared by the producer, the content of Mg, Ca, Na and K (mg 100 $kcal^{-1}$) in the analysed milk formulas was compared against the standard content (Journal of Laws 2007).

RESULTS

Starter infant formula

The content of Ca, Mg, Na and K in the studied products was presented in Table 3. The highest content of Mg was found in product IV (5.5 mg 100 ml^{-1}), the most Ca was determined in product V (more than 46 mg 100 ml^{-1}), Na was the most abundant in products II and III (nearly 20 mg 100 ml^{-1}), and product III contained the highest amount of K (more than 75 mg

Table 1

Description of the analysed samples of milk substitutes for infants

Trade mark	Use	Description of the product	kcal*
I	starter formula for infants from 1 month of age	Gluten-free, produced for infants who for various reasons cannot be breastfed.	66
II	milk for infants younger than 6 months	For infants allergic to cow's milk protein, food protein, suffer from colic or chronic diarrhoea. Contains hydrolysed protein with free aminoacids and also short-chain peptides. Contains prebiotics and long-chain fatty acids.	66
III	milk for infants from birth	Suitable for infants who cannot be breastfed and are susceptible to constipation and colic. Contains a composition of GOS/FOS oligosaccharides which soften the stool.	66
IV	starter formula for infants from birth to 6 months of age	Gluten-free milk used during treatment with antibiotics. Contains 13 vitamins and minerals (Fe, Mg, Ca, Se, I, Zn).	67
V	milk above 1 month of life	Containing a composition of GOS/FOS oligosaccharides, enriched with vitamin D and Ca, P and Fe.	68
VI	milk for infants older than six months	Used when the infant is hungry and wakes up at night. Contains corn and rice porridge, enriched with vitamin D and Ca.	68
VII	milk for infants from 6 months of age	Contains starch, hydrolysed protein, composition of fructooligosaccharides (FOS) and galacto-oligosaccharides (GOS), nucleotides and (LC PUFA). Hypoallergenic product.	66
VIII	follow-up milk for infants aged over 6 months	Used during the time of weaning, most similar to breast milk. Gluten-free milk containing OPTI PRO protein and BIFIDUS probiotic cultures.	67
IX	milk for babies older than 1 year	Gluten-free milk used during and after the period of weaning. Contains Zn, Fe, Ca, Se, I, Mg and Vit. D. Does not need boiling. Contains live cultures of BIFIDUS BL bacteria and OPTI PRO protein. The milk does not need boiling.	67
X	milk formula for babies older than 1 year	Milk formula for babies that were not breastfed, contains Ca, Fe and vitamins D_3, A and C. Made from defatted cow's milk, lactose, vegetable oils and whey protein. Contains the cultures of bacteria occurring in breast milk – *L. comfortis*.	66
XI	milk for babies older than 1 year	Contains a composition of GOS/FOS prebiotics (including fibre), Ca, Fe and Vit. D, alpha-linolenic acid.	65

* values as declared by the producer per 100 ml of the finished product

Table 2

Measurement parameters for the determination of Mg, Ca, Na and K

Specification	Mg	Ca	Na	K
Wavelength (nm)	202.6	422.7	589.0	766.5
Lamp current (mA)	4	10	-	-
Spectra band pass (nm)	1.0	0.5	0.2	0.2
LOD (mg kg^{-1})	18.0	28.0	20.0	20.0
LOQ (mg kg^{-1})	36.0	56.0	40.0	40.0
Pure gas	C_2H_2/air	C_2H_2/air	-	-
Deuter background correction	-	-	-	-
Mean recovery rate (%)	105	99	99	94
The deviation of duplicate measurement (%)	3.7	7.0	2.4	4.6
Quality control:				
Blank samples	yes	yes	yes	yes
CRM*	BCR-063R	BCR-063R	BCR-063R	BCR-063R

* The certified reference material (CRM) contained: Mg 1.263 mg g^{-1}, Ca 13.49 mg g^{-1}, Na 4.37 mg g^{-1}, K 17.68 mg g^{-1}.

100 ml^{-1}). The results obtained in the current studies were compared with values declared by the producers on product packaging (Table 3). In some cases certain discrepancies were found between the compared values. In the authors' analyses, values of ca. 25% lower than those declared were obtained for Mg (product V), ca. 10-15% lower for Ca (products I, II, III) and ca. 20% lower for Na (product V). The content of Mg, Ca, Na and K 100 $kcal^{-1}$ was within the standard limits (Table 4).

Follow-up formula for infants aged 6-12 months

The content of Mg in the studied preparations ranged from 5 (products VI, VII) to 6.6 mg 100 ml^{-1}, the content of Ca varied from 58 mg (product VII) to 74 mg (product VIII) 100 ml^{-1} of formula, the content of Na ranged from nearly 17 mg (product VI) up to 25 mg (products VII, VIII) 100 ml^{-1}, while the level of K in all analysed products was determined at ca. 80 mg 100 ml^{-1} (Table 3). Comparing the results of these analyses with the content declared by producers no significant differences were found between the values; it was only in products VII and VIII that the authors found ca. 5% less of Mg, while the content of Ca in product VI was ca. 8% lower than declared (Table 3). In addition, it was found that with regard to the Journal of Laws (2007), all the analysed products used from the 6^{th} to 12^{th} month of life, contained adequate amounts of Ca, Mg, Na and K (Table 4).

Table 3

Declared and measured content of Ca, Mg, Na and K (mg 100 ml^{-1}) in examined milk formulas

Products	Mg			Ca			Na			K		
	content		(%)	content		(%)	content		(%)	content		(%)
	declared*	measured		declared*	measured		declared*	measured		declared	measured	
Starter infant formula (0 - 6 months of age)												
I	5.1	5.3	103.9	47	42.1	89.6	17	16.6	97.6	65	63.3	97.4
II	5.1	4.9	96.1	47	41.2	87.7	20	19.9	99.5	75	74.3	99.1
III	5.5	5.4	98.2	49	41.1	87.7	20	19.6	98.0	75	75.1	100.1
IV	5.7	5.5	94.7	43	41.2	95.8	17	16.6	97.6	68	67.1	98.7
V	5.5	4.1	74.5	46	46.1	100.2	20	15.9	79.5	69	68.8	99.7
Follow-up formula for infants (6 - 12 months of age)												
VI	4.7	4.8	102.1	72	66.3	92.1	17	16.6	97.6	81	80.5	99.4
VII	5.4	5.1	94.4	62	58.4	94.2	25	25.4	101.6	78	77.7	99.6
VIII	6.8	6.6	97.1	77	74.4	96.6	26	24.7	95.0	75	80.8	107.7
Follow-up formula for infants (more than 12 months of age)												
IX	6.1	6.8	111.5	78.6	71.6	91.1	30.4	30.1	99.0	82.3	81.3	98.8
X	6.8	6.5	95.6	78	69.6	89.2	27	25.7	95.2	75	74.1	98.8
XI	6.0	5.7	95.0	129	120.7	93.6	19	19.1	100.5	84	83.6	99.5

* The declared values were adopted as 100%.

Table 4

Comparison of the content of Mg, Ca, Na and K (mg 100 $kcal^{-1}$) in the analysed milk formulas with the norm

Element	Norms (Journal of Laws 2007)	(mg 100 $kcal^{-1}$)										
		starter infant formula (0 - 6 months of age)					follow-up formula for infants (6 – 12 months of age)			follow-up formula for infants (more than 12 months of age)		
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Mg	5-15	8.0±0.01	7.4±0.03	8.2±0.34	8.2±0.02	6.0±0.14	7.1±0.23	7.7±0.03	9.9±0.02	10.1 ±0.02	9.7±0.31	8.8±0.28
Ca	50-160	63.8 ±1.21	62.4 ±1.42	62.3 ±2.32	61.5 ±0.95	67.8 ±0.71	97.5 ±0.36	88.5 ±1.28	111.0 ±0.81	106.9 ±0.67	103.9 ±1.31	185.7 ±4.521
Na	20-60	25.2 ±0.12	30.1 ±1.12	26.7±0.65	24.8 ±0.54	23.4 ±1.12	24.4 ±0.98	38.5 ±0.28	37.9 ±0.89	44.9 ±1.20	38.4 ±0.22	29.4 ±1.17
K	60-145	95.9 ±1.342	112.6 ±5.011	113.8 ±4.03	101.5 ±4.12	101.5 ±4.87	118.4 ±2.87	117.7 ±2.92	120.6 ±4.87	121.3 ±3.74	110.6 ±2.78	122.9 ±3.65

Follow-up formula for babies aged over 12 months

The formula for babies older than 12 months contained 6-6.8 mg Mg, 70-121 mg Ca, 19-30 mg Na and 74-84 mg K (Table 3). Considerable discrepancies between the findings of the study and the declaration of the producer were only reported for the level of Ca in products IX and X, where it was ca. 10% lower (Table 3). It was determined that the content of Ca in product XI exceeded by ca. 16% the level set in the standards, In the other products, the content of Mg, Ca, Na and K per 100 kcal did not deviate from standard values (Table 4).

DISCUSSION

The level of some minerals in infant milk formulas can be much higher in comparison to mother's milk, which is a result of their lower assimilability (Stolarczyk 2001). Some studies available in the literature have shown that infant and baby formulas have a carefully balanced mineral composition, both in Poland and in other countries. Witczak and Januszewska (2011) recorded that the content of Ca in infant formulas was lower than that declared by the producer; however, the daily supply of Ca exceeded the standard by 19-92%. Also, the supply of Mg, Na and K was higher than recommended. Winiarska-Mieczan and Tupaj (2009) found that the level of Ca in infant formulas was higher than that recommended by the relevant standards, while the level of Mg was lower. A deficiency of Mg and excessive amount of Ca was found by the analysis of infant formulas from the UK, USA and Nigeria (Ikem et al. 2002). Studies carried out in Brazil demonstrated that the level of Ca and K was higher than recommended (da Silva et al. 2013). When interpreting the excessive amount of Ca in infant formulas, factors reducing the absorption of this element must be taken into account, e.g. low assimilability of Ca amounting to ca. 38% compared to ca. 58% assimilated from breast milk (Greer et al. 2006). Also, a less favourable Ca:P ratio must be noted; in infant powdered milk it is 1:3, whereas in breast milk it is about 2:1 (Witczak, Januszewska 2011). Thus, an excess of this element should not be disturbing, the more so that a positive balance of Ca is particularly important in the period of growth and development of the body (Skrajnowska 2006). According to the Commission Directive of 2006, powdered milk formulas for infants and babies should contain from 50 to 140 mg Ca 100 $kcal^{-1}$, while according to the Polish Norm (Journal of Laws 2007) they should have from 50 to 160 mg Ca 100 $kcal^{-1}$. With regard to the standards, it should be noted that nearly all milk formulas analysed by the authors contained an adequate amount of this component, except one product, in which the level of Ca exceeded the acceptable amount by more than 20 mg (ca. 16%).

An insufficient supply of minerals for infants aged over 6 months is not alarming either, since infants at that age, in addition to milk, consume solid foods such as porridge, fruit desserts, fruit juices, soups and dinners, which, according to the current guidelines applicable in Poland, must be introduced gradually from the 5th month of the infant's life (Książyk, Weker 2007). Porridge products are particularly abundant in minerals since they contain: 60-90 mg Mg, 600-750 mg Ca and 450-800 mg K 100 g^{-1} (Melø et al. 2008). Other baby foods are also a good source of macroelements (Marzec et al. 2007, Melø et al. 2008, Winiarska-Mieczan, Nowak 2008, Marzec et al. 2009, Al Khalifa, Ahmad 2010).

CONCLUSIONS

The studied infant and baby formulas, and particularly starter formulas for infants younger than 6 months, were characterised by a satisfactory content of Mg, Ca, Na and K. In the case of infants older than 6 months, meals should be more diversified since a powdered milk formula covers their requirement of these components to a low extent. It must be stated that the analysed products are compliant with the Polish norms in terms of the content of Ca, Mg, Na and K.

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