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CONTENT OF Zn, Cu, Fe AND Mn IN PROCESSED FRUIT AND MIXED FRUIT AND VEGETABLE FOODSTUFFS FOR INFANTS

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Abstract

A baby's diet can be greatly varied by offering new tastes. Children tend to consume willingly fruit such as apples or bananas. The first fruit tastes may be recognized by children by enriching their menu with dessert products containing pressed fruit, delicate in taste and smooth in texture so that they are easy to swallow.

The research material consisted of fruit and vegetable desserts for infants and young children. Fifteen different types of desserts (in jars) from eight different manufacturers were tested. The content of Zn, Cu, Fe and Mn was determined by means of the AAS flame technique in a Unicam 939 (AA Spectrometer Unicam) apparatus. Although the permissible levels of Zn, Fe and Mn (Journal of Law 2007) were not exceeded in the dessert products, nearly all the products contained too much copper. The analyzed products contained the average of 282.2 mg of Zn per 100 kcal, 648.9 mg of Fe, 129.5 mg of Cu and 195.4 mg of Mn. Assuming that a baby aged 9-12 months consumes one jar of dessert daily, she/he ingests almost 0.27 mg of Zn (9% of the RDA), *ca* 0.63 mg of Fe (5.7% of the RDA), 0.12 mg of Cu (40% of the AI) and 0.21 mg of Mn from the product.

Fruit and vegetable products are an important source of mineral elements in the baby's diet. Because they usually contain less Zn and Mn in reference than demanded, they are a supplementary product rather than a staple one in infant nutrition.

Key words: baby food, infants, microelements.

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ZAWARTOŚĆ Zn, Cu, Fe I Mn W GOTOWYCH PRODUKTACH OWOCOWYCH I OWOCOWO-WARZYWNYCH PRZEZNACZONYCH DLA NIEMOWLĄT

Abstrakt

Bardzo istotną rolą urozmaicania diety jest poznawanie nowych smaków. Dzieci zazwyczaj chętnie jadają owoce o łagodnym smaku, np. jabłka lub banany. Pierwsze owocowe smaki w jadłospisie dziecko może poznać dzięki delikatnym deserkom, które zawierają przetarte owoce, mają łagodny smak i gładką konsystencję ułatwiającą przełykanie.

Materiał do badań stanowiły owocowo-warzywne desery przeznaczone dla niemowląt i małych dzieci. Badano 15 różnych typów deserów (w słoikach), wyprodukowanych przez ośmiu producentów. Zawartość Zn, Cu, Mn oraz Fe oznaczono za pomocą płomieniowej techniki AAS w aparacie Unicam 939 (AA Spektrometr Unicam). W badanych deserach dopuszczalny w polskiej normie (PN 2007) poziom Zn, Fe oraz Mn nie został przekroczony, natomiast zawartość Cu była zbyt wysoka. Badane produkty zawierały średnio 282.2 mg Zn 100 $kcal^{-1}$, 648.9 mg Fe, 129.5 mg Cu oraz 195.4 mg Mn. Przyjmując, że dziecko w wieku 9-12 miesięcy spożywa dziennie jeden słoik deseru, wraz z tym posiłkiem przyjmuje ok. 0.27 mg Zn (9% RDA), 0.63 mg Fe (5.7% RDA), 0.12 mg Cu (40% AI) oraz 0.21 mg Mn.

Produkty owocowo-warzywne są ważnym źródłem składników mineralnych w diecie dziecka. Ponieważ zawierają zwykle zbyt mało Zn i Mn w stosunku do zapotrzebowania, nie są produktem podstawowym w żywieniu niemowląt, a jedynie uzupełniającym.

Słowa kluczowe: żywność, niemowlęta, mikroelementy.

INTRODUCTION

Healthy nutrition during infancy is of fundamental importance to the development of children. Childhood is the time when any deficiency or excess of essential macro- or microelements may result in processes permanently affecting certain functions of an organism, also during the adulthood (KSIĄŻYK 2001). In order to attain all necessary nutritional goals, the diet of infants above six months of age should be enriched by supplementing it with adequate products (KSIĄŻYK, WEKER 2007).

A baby's diet can be greatly varied by offering new tastes. Children tend to consume willingly fruit such as apples or bananas. The first fruit tastes may be recognized by children by enriching their menu with dessert products containing pressed fruit, delicate in taste and smooth in texture so that they are easy to swallow. Moreover, fruit desserts facilitate introduction of fruit into a diet and are a valuable source of vitamin C, antioxidants and fiber in any season of the year (ČIŽKOVA et al. 2009). Fruit and vegetable products are also an important source of mineral elements in children's diet.

A mineral element may be regarded as essential for a human organism when its deficiency leads to characteristic syndromes, which recede a soon as the deficiency has been eliminated or when the function it plays in the organism has been explained. Such criteria apply to, for example, zinc, iron, copper and manganese. A serious consequence of low zinc intake, particularly in young children, is diarrhea alongside raised vulnerability to infections (HAMBIDGE, KREBS 2007). Zinc is indispensable to the synthesis of proteins and nucleic acids; it also regulates muscle contractibility and participates in the synthesis of insulin-like growth factor 1 (IGF-1) (MACDONALD 2000). Low plasma zinc concentration was associated with more severe liver disease (SCHNEIDER et al. 2009). An excessive amount of zinc may limit the absorption of copper and iron. Iron is a component of hemoglobin and myoglobin. Its lack leads to anemia, in the first place, and also to poorer concentration and mental agility (BEARD 2001). Iron overdose is rare. Copper deficiency leads to growth impairment and nervous system disorders, whereas its excess may become a cause of anemia, disorders in liver functioning and lower immunity (ZATTA, FRANK 2007). Manganese plays an important role in a number of physiologic processes in mammals and it is involved in the function of numerous organ systems (ASCHNER, ASCHNER 2005). Mn is needed for regulation of blood sugar, normal immune function, bone growth and reproduction. Too high supply of manganese is the cause of respiratory tract irritations (SOLDIN, ASCHNER 2007). Cumulative exposure to manganese causes neurotoxicity in both humans and animals. Occupational exposure to manganese by inhalation has been associated with manganism (ZAWADZKI et al. 2008). This condition occurs as a result of inhalation exposure to high levels of manganese and is not relevant to the assessment of lower levels of manganese in food. The absorption and retention of manganese from foods, low in iron, are relatively high (FINLEY, DAVIS 1999).

The aim of the study was to determine the content of selected mineral elements (zinc, copper, iron and manganese) in fruit and vegetable dessert products intended for the nutrition of babies and infants.

MATERIALS AND METHODS

Food samples

The research material consisted of fruit and vegetable desserts for infants and young children, purchased in shops in Lublin, in 2009, before their use-by date. Fifteen different types of desserts (in jars) from eight different manufacturers were tested: A-1 (ingredients: apple, pear, apple juice, wheat starch - gluten free, corn starch), A-2 (white grape juice, pear, plum, apricot, tapioca starch, rose hip), B (apple, peach, grape juice, water, sugar, corn starch), C-1 (apple, apricot), C-2 (banana, pineapple juice, orange juice, apple, corn starch, lemon juice), D (organic yoghurt, water, apple, bilberry, sugar, carrot juice), E-1 (apple, apricot, yoghurt), E-2 (apple, apricot), F-1 (apple juice, apple, cherry), F-2 (pear, apple), G-1 (apple, banana), G-2 (white grape juice, pear, plum, apricot, tapioca starch, rose hip), G-3 (apple, rose hip, grape juice, wheat starch - gluten free, corn starch), H-1 (banana, water, peach, rise flour, lemon juice, apple juice), H-2 (water, apple, banana, pear juice concentrate, rice starch, apricot, lemon juice).

The tested baby foods were made in Poland, Germany, Slovakia, the Czech Republic and Switzerland (Table 1).

Table 1

Characteristics of the analyzed fruit and mixed fruit and vegetable baby food

Trade mark	Remarks	Weight of a jar (g)	Manufactured in
A-1	food for special purposes	125	Poland
A-2	food for special purposes	125	Poland
B	food for special purposes	130	Poland
C-1	food for special purposes	130	Poland
C-2	food for special purposes	130	Poland
D	food for special purposes, organic food	125	Poland
E-1	food for special purposes	190	Slovakia
E-2	food for special purposes	190	Slovakia
F-1	organic food	190	Germany
F-2	organic food	190	Germany
G-1	food for special purposes	125	Czech Republic
G-2	food for special purposes	125	Czech Republic
G-3	food for special purposes	125	Czech Republic
H-1	food for special purposes, organic food	190	Switzerland
H-2	food for special purposes, organic food	190	Switzerland

Methods

Baby food samples were shaken manually before analysis. The content of raw ash in the samples was determined with the use of the AOAC method (1990). Approximately 10g of the analyzed material was weighed, the samples were dried at the temperature of 105°C for 48 hours and later mineralized in a zinc furnace at the temperature of 550°C for 16 hours. 10 ml of 6 N HCl was added to the mineralized samples and the solution was filtered to measuring flasks, where distilled water was added to the total volume of 50 ml. Stock solution was used in the analyses. The content of Zn, Cu, Fe and Mn was determined with the AAS flame technique in a Unicam 939 (AA Spectrometer Unicam) apparatus.

All the chemical analyses were conduced in three replications.

Calculations and statistical analysis

Referring to the energy value declared by the manufacturers (Table 2), proportions were calculated in the analyzed preparations between their particular components and energy (kcal). Additionally, the content of individual components in one jar was calculated.

Assuming that a 9-12-month-old child (who may eat all the examined products) consumes on average one jar of dessert daily, the percentage of the recommended intake of Zn, Cu and Fe was calculated. The RDA (recommended daily allowance) of zinc is 3 mg/pers./day and of iron it is 11 mg/pers./day (Jarosz, Bułhak-Jachymczyk 2008). The RDA of Cu an infant's diet has not been determined in Poland, while the AI (adequate intake) of copper is set at 0.3 mg/pers./day (Jarosz, Bułhak-Jachymczyk 2008). There is no recommended level of dietary Mn in Poland.

The results were subject to statistical analysis. The Statistica 6.0 software was used to calculate maximum, minimum and mean values, the standard deviation (SD), the standard error of the mean (SEM), and the median.

RESULTS

The standard Polish norm defining the maximum content of mineral elements in nutritional products intended for infants and young children determines proportions between particular ingredients and the energy value in kcal. The content of minerals in the analyzed products, calculated per 100 kcal, is presented in Table 2. The acceptable value of Zn, Fe and Mn was not exceeded in the dessert products (Journal of Law 2007) but nearly all the products contained too much copper. The analyzed products contained the average of 282.2 mg of Zn per 100 kcal and 129.5 mg of Cu, 648.9 mg of Fe and 195.4 mg of Mn.

Table 3 presents the content of minerals in the dessert products, calculated per 1 kg of the product, whereas Figure 1 shows the content of these minerals in one jar. The content of zinc ranged from 0.19 to 6.67 mg in 1 kg; the highest concentration of Zn was noted in the product F-2. All the desserts had a very high content of copper: on average 0.81 mg in 1 kg of the product (0.23-1.19 mg). The highest copper concentration was determined in products labeled as A-1, C-1, F-1, G-2, G-3, H-1 and H-2 (above 1 mg in 1 kg of natural mass). The highest concentration of Fe was observed in the products marked as G-2 and H-1 (*ca* 10-11 mg in 1 kg). The content of manganese ranged from 0.25-4.74 mg in 1 kg. The highest concentration was noted in the product labeled as F-1.

Table 2

Contents of Zn, Cu, Fe, Mn and energy in fruit and mixed fruit and vegetable baby food

Trade mark	Zn	Cu	Fe	Mn	Energy, kcal in 100 g **
	(μg 100 kcal⁻¹)				
A-1	97.42	144.28 *	513.28	84.28	70
A-2	139.42	125.79 *	634.92	209.13	69
B	399.86	126.31 *	566.31	221.97	64
C-1	368.66	236.66 *	273.55	55.33	46
C-2	143.18	86.66 *	163.33	38.33	84
D	322.89	29.73	24.47	438.15	76
E-1	189.83	72.88 *	184.75	83.05	59
E-2	306.38	93.62 *	421.28	140.43	47
F-1	271.66	115.11 *	383.57	564.16	50
F-2	1450.86	131.52 *	448.04	65.86	51
G-1	66.67	84.13 *	757.14	169.8	63
G-2	27.54	168.12 *	1576.81	159.42	69
G-3	54.69	185.94 *	1364.06	87.50	64
H-1	241.27	185.71 *	1500.00	458.73	63
H-2	152.31	156.92 *	921.54	155.38	65
Mean value	282.18	129.5 *	648.87	195.43	62.7
Polish Norm (Jornal of Laws 2007)	2000	40	3000	600	

* excessive levels in comparison with norms
** values as declared by the manufacturer

Assuming that a baby aged 12 months consumes one jar of dessert daily, she/he takes in almost 0.27 mg of Zn (9% of the RDA), *ca* 0.63 mg of Fe (5.7% of the RDA), 0.12 mg of Cu (40 % of the AI) and 0.21 mg of Mn from the analyzed products (Table 4).

DISCUSSION

Processed foodstuffs for infants are not highly trusted by parents. Some research has shown that only 22% of the parents regularly feed their children such products (WINIARSKA-MIECZAN, GIL 2007). A study performed by these authors revealed that the most popular products are fruit and vegetable desserts, with ready dinners served much less frequently. Among desserts and fruit and vegetable purees, the most popular are those prepared from home-grown fruit, especially apples, as well as the products containing ba-

Table 3

Contents of crude ash, Zn, Cu, Fe and Mn in fruit and mixed fruit and vegetable baby food (n=3)

Trade mark	Crude ash (%)	Zn	Cu	Fe	Mn
		(mg kg^{-1} natural mass)			
A-1	0.09	0.68	1.01	3.59	0.59
A-2	0.16	0.96	0.87	4.38	1.44
B	0.17	3.04	0.96	4.30	1.69
C-1	0.12	1.66	1.07	1.23	0.25
C-2	0.25	0.95	0.57	1.08	0.25
D	0.16	2.45	0.23	0.19	3.33
E-1	0.11	1.12	0.43	1.09	0.49
E-2	0.09	1.44	0.44	1.98	0.66
F-1	0.21	2.28	0.97	3.22	4.74
F-2	0.11	6.67	0.61	2.06	0.30
G-1	0.23	0.42	0.53	4.77	1.07
G-2	0.19	0.19	1.16	10.88	1.10
G-3	0.27	0.35	1.19	8.73	0.56
H-1	0.26	1.52	1.17	9.45	2.89
H-2	0.21	0.99	1.02	5.99	1.01
Mean value	0.18	1.65	0.81	4.20	1.36

nanas (GÓRECKA et al. 2007). Desserts are the first fruit meal in an infant's diet. They contain pressed fruit, are delicate in taste and smooth in consistency, which makes them easy to swallow. Additionally, fruit desserts facilitate introduction of fruit into babies' diet and provide a valuable source of vitamin C, as well as an important source of mineral elements.

The recommended daily allowance of zinc in infants up to 12 months of age in Poland is 3 mg/individual (JAROSZ, BUŁHAK-JACHYMCZYK 2008). Zinc deficiency is common in developed countries (BLACK 2003). It is believed that zinc deficiency inhibits children's growth and may lead to mental retardation (BHATNAGAR, NATCHU 2004). According to Norwegian studies, the content of zinc in fruit purees was 0.11 mg per 1 kg of the product (MELŘ et al. 2008). Breast milk and cereal gruel provide a good source of zinc, with the mean content of zinc in breast milk in Poland being 1.57 mg per 1 liter (STOLARCZYK 2001).

Any excess of mineral elements may also disturb the baby's development. Turkish studies revealed that food for infants may contain as much as 4 mg of copper per 1 kg of the product (SARACOGLU et al. 2007). In contrast, some analyses completed in Norway showed that fruit puree contained as much as 3.3 mg of copper per 1 kg of the product and 0.53 mg was found

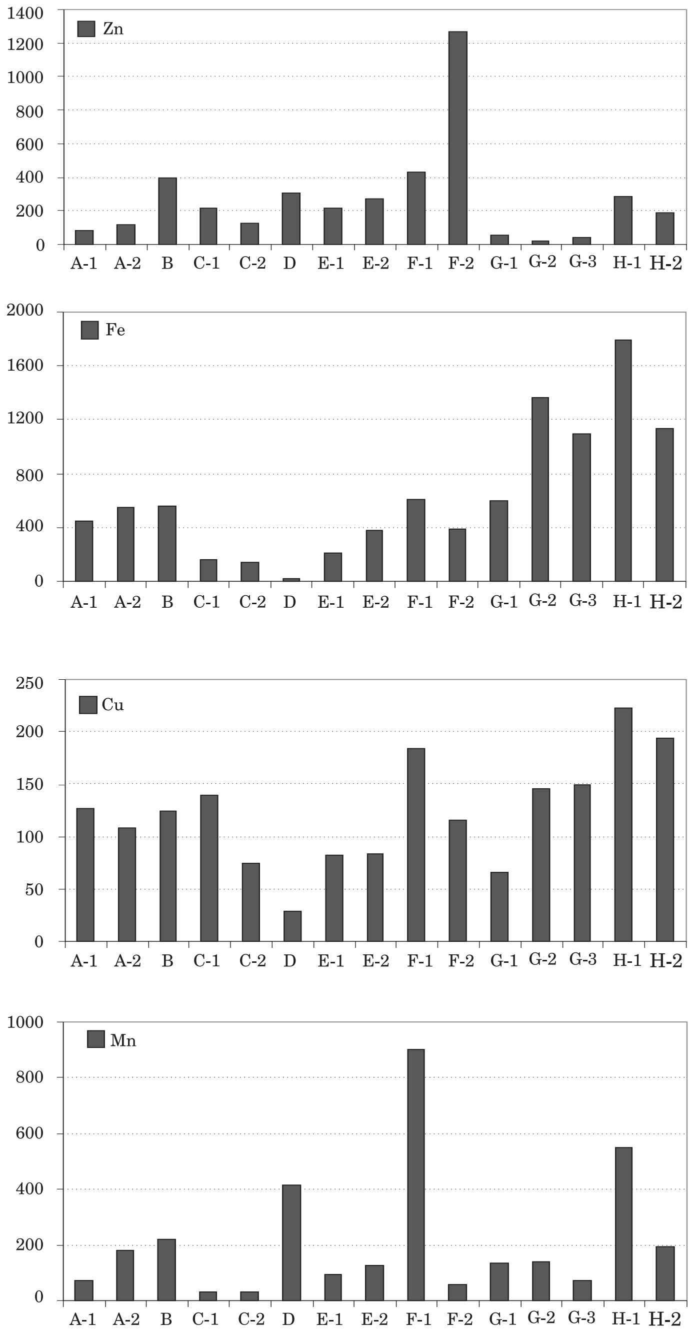

Fig. 1. Content of Zn, Cu, Fe and Mn (μg) in fruit and mixed fruit and vegetable products, in a jar (values calculated)

Table 4

Results of analyses of the fruit and vegetable baby food

Descriptive statistics	In jar			
	Zn (mg)	Cu (mg)	Fe (mg)	Mn (mg)
Maximum	1.27	0.22	1.79	0.90
Minimum	0.02	0.03	0.02	0.03
Mean	0.27	0.12	0.63	0.21
Median	0.21	0.12	0.55	0.13
SD	0.30	0.05	0.50	0.24
SEM	0.08	0.13	0.13	0.06
Mean daily intake *	0.27	0.12	0.63	0.21
Recommended level **	3	0.3	11	-
% of recommendation	9	40	5.7	-

SD – standard deviation, SEM – standard error of the means;
* Assuming that a 12-month-old child consumes on average one jar of dessert daily.
** JAROSZ, BUŁHAK-JACHYMCZYK (2008)

in 1 kg of fruit puree (MELŘ et al. 2008). A study performed by WINIARSKA-MIECZAN and NOWAK (2008) proved that in Poland the level of copper in juices for infants was high and in some products reached nearly 0.9 mg per 1 kg of the product. Excessive supply of copper leads to metabolic changes and its far-reaching consequences are related mainly to changes in the liver and, consequently, to damaging the kidneys, brain tissues, coronary vessels and the heart muscle. The most common consequences of excessive consumption of copper include mental disorders, kidney damage and hypertension (BREWER 2007, HUSTER et al. 2007). The recommended adequate intake of copper in infants up to 12 months of age in Poland is 0.3 mg/pers./day (JAROSZ, BUŁHAK-JACHYMCZYK 2008).

According to Polish studies, the average content of iron in fruit dessert and fruit juices for infants was, respectively, 2.73 mg and 1.80 mg per 1 kg of the product (MARZEC et al. 2007). Higher amounts of iron were found in baby soups (mean 3.29 mg kg^{-1}) and dinners (mean 3.83 mg kg^{-1}) (MARZEC et al. 2007). The content of iron in Turkish infant formulas has been reported in the range of 1.02-67.5 mg per 1 kg (SARACOGLU et al. 2007). The recommended daily allowance of iron in infants up to 12 months of age in Poland is 11 mg/individual (JAROSZ, BUŁHAK-JACHYMCZYK 2008). Young children are at higher risk of iron deficiency. Among children, iron deficiency is seen most often between 6 months and 2 years of age due to their rapid growth and an inadequate intake of dietary iron (HEATH et al. 2002). Iron deficiency is the most common form of nutritional deficiency and its incidence is the highest among young children (YEUNG, KWAN 2002).

A study performed by Marzec (2003) on fruit desserts and purees and fruit and mixed fruit and vegetable juices revealed that consuming such products did not satisfy the infant's daily demand for manganese, therefore the child's daily diet must be supplemented with this element by other groups of products, e.g. vegetable and meat products or, possibly, mineral supplementation. According to Marzec et al. (2007), the content of Mn in baby fruit desserts was 1.22 mg per 1 kg of the product. A study carried out in Spain showed that the content of Mn in fruit desserts intended for infants amounted to 0.66 mg in 1 kg of the product (Vinas et al. 2000). Milk formulas are a good source of manganese for children (Ikem et al. 2002, Winiarska-Mieczan, Tupaj 2009). There is no recommended level set in Poland for Mn but Marzec (2003) claims that the recommended daily demand for this element by infants up to 12 months of age is 0.6-1 mg.

CONCLUSIONS

The acceptable value of Zn, Fe and Mn (Journal of Law 2007) was not exceeded in dessert products. In contrast, nearly all the products contained too much copper. The analyzed products contained the average of 282.2 mg of Zn per 100 kcal, 648.9 mg of Fe, 129.5 mg of Cu, and 195.4 mg of Mn. Assuming that a baby aged 9-12 months consumes one jar of dessert daily, she/he takes in almost 0.27 mg of Zn (9% of the RDA), 0.63 mg of Fe (5.7% of the RDA), 0.12 mg of Cu (40% of the AI) and 0.21 mg of Mn from these products.

Fruit and vegetable products are an important source of mineral elements in the baby's diet. Because they usually contain too little Zn, Fe and Mn in reference to the demand, they are only a supplementary product rather than a staple one in infant nutrition.

REFERENCES

AOAC 1990. *Official methods of analysis (15th ed.)*. Washington, DC: Association of Official Analytical Chemists.

Aschner J.L., Aschner M. 2005. *Nutritional aspects of manganese homeostasis*. Molec. Aspects Med., 26: 353-362.

Beard J.L. 2001. *Iron biology in immune function, muscle metabolism and neuronal functioning*. J. Nutr., 131: 568-580.

Bhatnagar S., Natchu U.Ch.M. 2004. *Zinc in child health and disease.* Ind. J. Pediatr., 71(11): 991-995.

Black M.M. 2003. *The evidence linking zinc deficiency with children's cognitive and motor functioning*. J. Nutr., 133: 1473-1476.

Brewer G.J. 2007. *Iron and copper toxicity in diseases of aging, particularly atherosclerosis and Alzheimer's disease.* Exp. Biol. Med. (Maywood)., 232: 323-335.

ČIŽKOVA H., ŠEVČIK R., RAJCHL A., VOLDŘICH M., 2009. *Nutritional quality of commercial fruit baby food*. Czech J. Food Sci., 27(Special issue): 134-137.

FINLEY J.W., DAVIS C.D. 1999. *Manganese deficiency and toxicity: Are high or low dietary amounts of manganese cause for concern?* BioFactors, 10(1): 15-24.

GÓRECKA D., SZCZEPANIAK B., SZYMANDERA-BUSZKA K., FLARCZYK E. 2007. *Popularity of processed foodstuffs for infants and small children among parents*. Acta Sci. Pol. Technol. Aliment., 6(4): 123-133.

HAMBIDGE K.M., KREBS N.F. 2007. *Zinc deficiency: a special challenge.* J. Nutr., 137: 1101-1105.

HEATH A.L.M., TUTTLE C.R., SIMONS M.S.L., CLEGHORN CH.L., PARNELL W.R. 2002. *Longitudinal study of diet and iron deficiency anaemia in infants during the first two years of life.* Asia Pacific J. Clin. Nutr., 11(4): 251-257.

HUSTER D., PURNAT T.D., BURKHEAD J.L., RALLE M., FIEHN O., STUCKERT F., OLSON N.E., TEUPSER D., LUTSENKO S. 2007. *High copper selectively alters lipid metabolism and cell cycle machinery in the mouse model of Wilson disease*. J. Biol. Chem., 282: 8343-8355.

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: 439-447.

JAROSZ M., BUŁHAK-JACHYMCZYK B. (Ed.) 2008. *Normy żywienia człowieka. Podstawy prewencji otyłości i chorób niezakaźnych [Human nutrition norms. Guidelines for prevention of obesity and non-infectious diseases].* Wyd. PZWL, Warszawa. (in Polish)

Journal of Law 2007. T*he official journal of the Polish State*, No 209, item 1518.

KSIĄŻYK J. 2001. *Wpływ diety dziecka na jego rozwój i występowanie chorób wieku dorosłego [Effect of a child's diet on the development and incidence of adulthood diseases].* Pediatr. Współ. Gastroenterol. Hepatol. Żywienie Dziecka, 3(1): 7-9. (in Polish)

KSIĄŻYK J., WEKER H. 2007. *Nowe zalecenia żywienia niemowląt w Polsce od roku 2007 [New guidelines for infant nutrition in Poland since 2007].* Pediatr. Współ. Gastroenterol. Hepatol. Żywienie Dziecka, 9(4): 292-297. (in Polish)

MACDONALD R.S. 2000. *The role of zinc in growth and cell proliferation.* J Nutr., 130: 1500--1508.

MARZEC A. 2003. *Badanie poziomu magnezu, żelaza i manganu w produktach spożywczych przeznaczonych do żywienia niemowląt i dzieci [Testing levels of magnesium, iron and manganese in foodstuffs for infants and children].* Żyw. Człow. Metab., 1/2: 458-463. (in Polish)

MARZEC A., MARZEC Z., ZARĘBA S. 2007. *Magnesium, iron and manganese in some food products designed for nutrition of infants.* Pol. J. Environ. Stud., 16(3A): 198-201.

MELŘ R., GELLEIN K., EVJE L., SYVERSEN T. 2008. *Minerals and trace elements in commercial infant food.* Food Chem. Toxicol., 46(10): 3339-3342.

SARACOGLU S., SAYGI K., OZGUR O., ULUOZLU D., TUZEN M., SOYLAK M. 2007. *Determination of trace element contents of baby foods from Turkey*. Food Chem., 105: 280-285.

SCHNEIDER A.C.R., PINTO R.B., FRÖEHLICH P.E., HAMMES T.O., DA SILVEIRA T.R. 2009. *Low plasma zinc concentrations in pediatric patients with cirrhosis*. J. Pediatr. (Rio J.), 85(4): 359-364.

SOLDIN O.P., ASCHNER M. 2007. *Effects of manganese on thyroid hormone homeostasis: Potential links*. Neurotoxicology, 28(5): 951–956.

STOLARCZYK A. 2001. *Vitamins and minerals in infant formulas and special formulas*. Pediatr. Współ. Gastroenterol. Hepatol. Żywienie Dziecka, 3(2): 153-158. (in Polish, English abstract)

VIŃAS P., PARDO-MARTÍNEZ M., HERNÁNDEZ-CÓRDOBA M. 2000. *Determination of copper, cobalt, nickel, and manganese in baby food slurries using electrothermal atomic absorption spectrometry.* J. Agric. Food Chem., 48(12): 5789–5794.

WINIARSKA-MIECZAN A., GIL G. 2007. *Evaluation of the infant's exposure to lead and cadmium in the ready-cooked food*. Bromat. Chem. Toksykol., 2: 137-144. (in Polish, English abstract)

WINIARSKA-MIECZAN A., NOWAK K. 2008. *Determining the content of chosen minerals in fruit-vegetable baby juices.* J. Elementol., 13(3): 433-442.

WINIARSKA-MIECZAN A., TUPAJ M. 2009. *Evaluation of the mineral composition of infant formulas.* J. Elementol., 14(2): 583-591.

YEUNG D.L., KWAN D. 2002. *Commentary: Experiences and challenges in industrialized countries*. J. Nutr., 132: 825-826.

ZATTA P., FRANK A. 2007. *Copper deficiency and neurological disorders in man and animals*. Brain Res. Rev., 54(1): 19-33.

ZAWADZKI M., PAWLAS K., NIEDŹWIEDŹ A., MURAWSKA-CIAŁOWICZ E., JANUSZEWSKA L., NICPOŃ J. 2008. *Evaluation of oxidative stress in manganese intoxication in the rat's brains.* Med. Wet., 64(6): 836-839. (in Polish, English abstract)