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ORIGINAL PAPER

Milk slices as a source of macroelements and microelements in the diet of pre-schoolers

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Abstract

Sponge cake bars with milk filling, commonly referred to as milk slices, are a very frequent choice among children. These products are considered convenience foods consumed for breakfast and snacks during the day. They owe their popularity to commercials promoting these sweets as products that, in terms of calcium content, can successfully replace a glass of milk. Unfortunately, due to such associations, young consumers habitually choose highly sweetened products of low nutritional value. Since milk slices are very popular components of children's diets, they should be a source of essential nutrients, including mineral elements. This paper aimed to assay the level of selected macroelements (Ca, Mg, K, and Na) and microelements (Fe, Cu, and Zn) in sponge cake bars of milk slice type (n=15). The mean content of macroelements in the analysed products can be represented as K (3724 mg kg^{-1} ± 502.0) > Na (2703 mg kg^{-1} ± 2366) > Ca (1393 mg kg^{-1} ± 646.7) > Mg (489.4 mg kg^{-1} ± 211.9). The mean content of microelements in the analysed products can be represented as Fe (24.53 mg kg^{-1} ± 13.19) > Zn (8.946 mg kg^{-1} ± 2.444) > Cu (2.188 mg kg^{-1} ± 0832.7). When considering the daily requirement of pre-schoolers (aged 4-6) for the analysed minerals, it was established that, on average, one serving of a milk slice (31.7 g) supplies 17.9% RDA Cu, 12.5% RDA Mg, 10.7% AI K, 9.2% AI Na, 8.0% RDA Fe, 5.8% RDA Zn, and 4.1% RDA Ca. Our findings imply that milk slices are not a good source of minerals in pre-schoolers' diets.

Keywords: cereal bars, children's nutrition, milk slices, minerals, sponge cake

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INTRODUCTION

Sweet snacks are a daily component of the diets of both adults and children (Kmiecik et al. 2016). Nutrition experts recommend reducing the consumption of sugar and confectionery products. However, it is observed that sweets are invariably a popular choice of consumers (Maćków et al. 2020). Since these products are very popular components, they should be a source of essential nutrients, including minerals. Consumers perceive milk slices as highly nutritional products because commercials portray them as a source of calcium and an energy snack after breakfast.

Pre-schoolers' excessive or insufficient energy and nutrient intake can prevent their full psychophysical development and optimum health. A child spends about six or seven hours a day at nursery school, so the quality of food in the meals served to them is important.

It should be remembered that growing children are particularly sensitive to all food deficiencies (Orkusz, Włodarczyk 2014). Over the first three years of the child's life, their brain achieves

a weight that is only 200 grams smaller than the completely developed adult brain. Therefore, special attention should be paid to supplying the child with all nutrients, including macro- and microelements, necessary for the correct development of the structure and functions of the brain and all the other body organs and systems (Anjos et al. 2013). Surveys covering the population of pre-schoolers in Poland showed that their diets are poor, among other elements, in calcium (Kwiecień et al. 2015) and vitamin D (Dymkowska-Malesa, Szparaga 2013). The deficiency of vitamins D and K2 and calcium is the main reason for insufficient mineralisation of the skeletal system and low peak bone mass (Zaręba et al. 2012). This group of consumers is also characterised by insufficient intake of iron, which increases the child's susceptibility to respiratory infections and disorders of cognitive functions (Libera et al. 2018), and potassium showing antagonistic activity to sodium (Eckel et al. 2014). As regards sodium, its excess in the diet is a more common problem than its deficiency (Kwiecień et al. 2015), mostly due to the consumption of food with a considerable addition of table salt (Surma et al. 2020). Excessive salt intake increases the risk of hypertension (Eckel et al. 2014) and obesity (Kwiecień et al. 2017).

This paper aimed to estimate whether milk slices are a good source of selected macroelements: calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and microelements: iron (Fe), copper (Cu), and zinc (Zn) in the diet of pre-schoolers.

MATERIAL AND METHODS

Study material

Milk slices (*n*=15; Figure 1) and 2% cow's milk (*n*=10) were purchased at groceries in Lublin, between January and May 2021. All the products were ahead of their use-by dates. After the bars were ground in a laboratory grinder (Bosch, München, Germany), 3 g of the sample were weighed

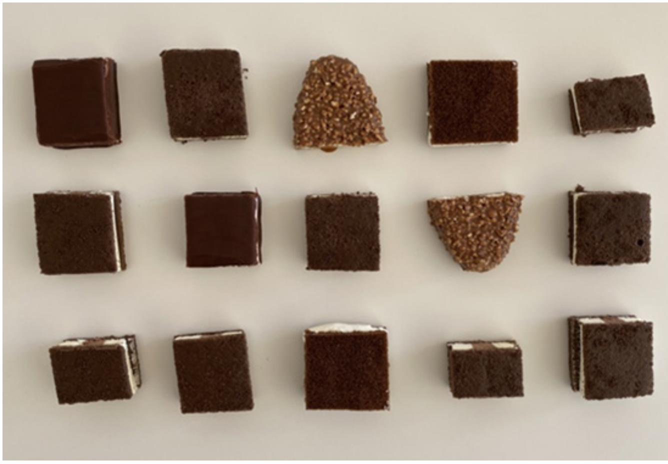

Fig. 1. Analysed milk sandwich bars

in three replications. The milk was mixed manually, and ca. 3 g of the sample was weighed. All the samples were dried in a WTB Binder dryer (Labortechnik GmbH, Tuttlingen, Germany) at 105°C for 12 h, and then mineralised in a muffle furnace (FCF 22 SHM, Czylok, Jastrzębie Zdrój, Poland) using hydrogen peroxide as an oxidant (temperature 550°C, 12 h). White ash from mineralisation was dissolved in 10 ml of 1M HNO_3. The content of Na, K, Ca, Mg, Zn, Cu, and Fe was assayed using ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometers) in a 720-ES spectrometer (Varian, Palo Alto, CA, USA). The mineral assay parameters are presented in Table 1. Detailed methods are described elsewhere (Winiarska-Mieczan et al. 2018, Jachimowicz et al. 2021).

Calculations and statistical analysis

The levels of Na, K, Ca, Mg, Zn, Cu and Fe in milk slices were given per product serving, one serving equivalent to one bar (16-50 g; on average 31.7 g). In addition, we calculated the extent to which one product serving covered the requirement of pre-schoolers (aged 4-6) for minerals according to the current Nutrition Standards for the Population of Poland, that is, AI (adequate intake) for Na and K, and RDA (recommended daily allowance) for Ca, Mg, Fe, Zn, Cu (Jarosz et al. 2020). The results were processed

Table 1

Parameters for the determination of minerals

Minerals	Wavelength (nm)	LOD (mg kg^{-1})	LOQ (mg kg^{-1})
Na	589.6	0.250	0.390
K	769.9	1.040	1.270
Ca	422.7	0.030	0.050
Mg	280.3	0.030	0.080
Zn	202.5	0.060	0.090
Cu	213.6	0.030	0.060
Fe	238.2	0.030	0.050

LOD – limit of detection, LOQ – limit of quantification

in Microsoft Excel 2010. Statistical analysis of results was carried out by one-way analysis of variance (ANOVA) using Statistica 13.1 software (StatSoft, Krakow, Poland). The Duncan's test established statistically significant differences ($P<0.05$). Correlations between minerals were calculated using the Pearson's correlation coefficient.

RESULTS AND DISCUSSION

The content of macro- and microelements in respective milk slices is presented in Table 2. The content of the analysed minerals differed depending on the composition of milk slices. One serving contained from 11.23-63.48 mg Ca, 6.53-52.3 mg Mg, 62.1-169.6 mg K, 6.28-377.2 mg Na, 0.102-1.951 mg Fe, 0.015-0.137 mg Cu and 0.137-0.620 mg Zn. Bar no. 2 featured the highest ($P<0.05$) content of all elements, except Ca, Mg and Zn, and bar no. 10 – the lowest ($P<0.05$) content of all elements, except Ca, Na and Cu. The mean level of micro- and macroelements in the analysed products per average serving (31.7 g), referring to requirement coverage, can be presented as Cu (0.07 mg ± 0.04) > Mg (16.3 mg ± 11.0) > K (117.6 mg ± 30.9) > Na (91.8 mg ± ± 100.9) > Fe (0.8 mg ± 0.5) > Zn (0.29 mg ± 0.1) > Ca (40.9 mg ± 17.3). The biggest difference between the minimum and maximum values was observed for Na, and the smallest for K.

Statistically significant ($P<0.05$) positive correlations between minerals contained in milk slices were observed only for Mg and Zn ($r=0.795$) and for Cu and Zn ($r=0.637$) (Table 3).

Calcium

One milk slice serving, on average, supplied nearly 41 mg Ca (1393 mg kg^{-1} ± ± 646.7), which covered 4.1% of the requirement (1000 mg) of children aged 4-6 for that element (Table 4). The findings of Pagamunici et al. (2014) were

Table 2

The content of minerals in 1 serving of milk sandwich bar (*n*=15)

n	Package weight	Ca (mg)	Mg (mg)	K (mg)	Na (mg)	Fe (mg)	Cu (mg)	Zn (mg)
1	28	50.82^{e}	12.34^{d}	122.7^{e}	35.53^{d}	1.071^{h}	0.051^{cd}	0.218^{b}
2	50	18.24^{b}	21.54^{h}	169.6^{g}	257.5^{k}	1.951^{j}	0.137^{h}	0.447^{i}
3	30	50.02^{e}	14.10^{e}	107.4^{c}	21.09^{b}	0.989^{h}	0.074^{e}	0.313^{f}
4	29	61.08^{f}	11.94^{c}	102.0^{c}	75.93^{h}	0.552^{e}	0.045^{c}	0.199^{c}
5	30	57.18^{f}	19.72^{h}	121.7^{e}	25.27^{bc}	0.459^{d}	0.116^{g}	0.417^{h}
6	32	11.23^{a}	12.67^{d}	86.70^{b}	66.12^{g}	0.564^{e}	0.075^{e}	0.220^{cd}
7	29	63.48^{f}	9.950^{b}	125.3^{e}	155.5^{j}	0.877^{gh}	0.044^{c}	0.195^{b}
8	32	51.00^{e}	17.90^{g}	128.9^{e}	60.06^{fg}	0.694^{f}	0.068^{e}	0.276^{e}
9	29	52.20^{ef}	6.530^{a}	80.60^{b}	95.61^{i}	0.196^{b}	0.015^{a}	0.145^{a}
10	16	24.67^{c}	6.810^{a}	62.11^{a}	28.93^{c}	0.102^{a}	0.033^{b}	0.137^{a}
11	28	47.19^{e}	9.460^{b}	99.61^{c}	57.62^{f}	1.074^{h}	0.038^{b}	0.255^{d}
12	28	48.23^{e}	12.89^{d}	113.9^{d}	46.91^{e}	0.343^{c}	0.055^{d}	0.293^{f}
13	40	15.24^{ab}	20.77^{h}	168.1^{g}	377.2^{l}	0.837^{g}	0.137^{h}	0.358^{g}
14	45	30.07^{d}	52.35^{i}	160.0^{f}	6.281^{a}	0.804^{g}	0.106^{g}	0.620^{j}
15	30	33.27^{d}	15.03^{f}	115.0^{d}	67.39^{g}	1.540^{i}	0.081^{f}	0.245^{d}
Average (for 31.7 g)		40.93	16.27	117.6	91.80	0.804	0.072	0.289
Maximum		63.48	52.35	169.6	377.2	1.951	0.137	0.620
Minimum		11.23	6.530	62.10	6.280	0.102	0.015	0.137
SD		17.27	11.02	30.91	100.9	0.491	0.038	0.128
Variance analysis		298.4	121.4	955.6	10183	0.241	0.001	0.016

SD – standard deviation; $^{a, b, c, \dots}$ – values with different superscripts differ at P<0.05 by the Duncan's test.

Table 3

Pearson correlations coefficients for minerals in milk sandwich bars

Minerals	Ca	Mg	K	Na	Fe	Cu	Zn
Ca	1.000	-0.318	0.346	-0.325	-0.053	-0.467	-0.128
Mg	-0.318	1.000	0.179	-0.309	-0.245	0.457	**0.795**
K	0.346	0.1798	1.000	0.183	-0.022	0.254	0.294
Na	-0.325	-0.309	0.183	1.000	0.093	0.136	-0.364
Fe	-0.053	-0.246	-0.022	0.093	1.000	-0.099	-0.263
Cu	-0.467	0.457	0.254	0.136	-0.099	1.000	**0.637**
Zn	-0.128	**0.795**	0.294	-0.364	-0.263	**0.637**	1.000

Values significant at $P \leq 0.05$ are highlighted in bold

Table 4

Demand of children aged 4-6 for selected macro- and microelements and their intake with 1 average portion of the product (31.7 g)

Minerals	Demand (mg) (Jarosz et al. 2020)	Intake with 1 serving (mg)	Coverage of demand (%)
Ca	1000	40.9	4.1
Mg	130	16.3	12.5
K	1100	117.6	10.7
Na	1000	91.8	9.2
Fe	10	0.8	8
Cu	0.4	0.07	17.9
Zn	5	0.29	5.8

to the contrary. The main element of gluten-free amaranth bars they analysed was Ca. In the study of Agbaje et al. (2014), the content of Ca in rice flake cereal bars ranged from 186.54 to 482.89 mg kg^{-1}, which is lower than the value we measured. On average, the Ca content in apricot-date bars was 1018 mg kg^{-1} of the product (Rehman et al. 2012). Compared with the results of Ananthan et al. (2012), the high-protein cereal bar contained only 8.9 mg Ca kg^{-1}. Thus, it can be claimed that milk slices contain more Ca than bars of other types, but still, these amounts are insufficient to be regarded as a good source of Ca in the diet. Dymkowska-Malesa and Szparaga (2013), evaluating the diets of the pre-school population, found that Ca was the most frequently deficient mineral. Children's diets are poor in Ca (up to 70% deficiencies) in relation to the growing body's needs (Zyśk et al. 2020). An insufficient supply of Ca in a diet is an adverse practice. This is particularly dangerous for young children since deficient levels of Ca are refilled at the expense of bone tissue, which increases the rate of decreasing bone density. Calcium is the most essential mineral for building bones and teeth (Zyśk et al. 2020). Excessive fat intake from milk slices and protein reduces Ca absorption from the gastrointestinal tract and contributes to increased excretion of Ca with urine (Orkusz, Olech 2014).

Magnesium

One milk slice serving, on average, supplied nearly 16.3 mg Mg (489.4 mg kg^{-1} ± 211.9), which covered 12.5% of the requirement (130 mg) of children aged 4-6 for that element (Table 4). According to Bancerz et al. (2012), a 50 g milk bar contains 28 mg Mg, which is nearly equivalent to one serving of 2% fat milk. In the study of Agbaje et al. (2014), the content of Mg in cereal bars ranged from 88 to 160.14 mg kg^{-1}, which is more than three times lower than the value we measured. By contrast, Pagamunici et al. (2014) demonstrated that cereal bars contained much more Mg – on average, 2799 mg kg^{-1} – compared with our findings. Goluch-Koniuszy's (2010) study shows that Polish children consume less Mg than required (covering 73-83% of the requirement). Kwiecień et al. (2015) evaluated the supply of Mg in a pre-schooler's food ration as correct (covering 86% of the requirement), but Dymkowska-Malesa and Szparaga (2013) and Zyśk et al. (2020) observed that the supply of Mg in the diet of pre-schoolers was above standard (183-226% of the requirement). A statistically significant positive correlation was identified between the level of cognitive development of children aged 4-6 and the intake of Mg (Zyśk et al. 2020). Some researchers found that children with attention deficit hyperactivity disorder (ADHD) had considerably lower levels of Mg in the blood serum than healthy children (Effatpanah et al. 2019), but a random blind study did not confirm that Mg supplementation could be effective in the treatment of such disorders (Ghanizadeh 2013).

Potassium

One milk slice serving, on average, supplied about 118 mg K (3724 mg kg^{-1} ± ± 502), which covered nearly 11% of the requirement (1100 mg) of children aged 4-6 for that element (Table 4). In the study of Rehman et al. (2012), the content of K in dried fruit bars was 6400 mg kg^{-1} product. The difference between the content of K in milk slices and apricot-date bars can be due to the fact that dried fruit is a good source of K in the diet (Kunachowicz et al. 2020). The study by Kwiecień et al. (2015) attested to the insufficient intake of K by pre-schoolers (covering 27% of the requirement). A diet poor in K and rich in Na is a risk factor for developing hypertension (Lava et al. 2015).

Sodium

One milk slice serving, on average, supplied ca. 92 mg Ca (2703 mg kg^{-1} ± ± 2366), which covered 9.2% of the requirement (1000 mg) of children aged 4-6 for that element (Table 4). The content of Na in rice flakes cereal bars ranged from 70.54 to 235.86 mg kg^{-1} (Agbaje et al. 2014), which was much lower than what we measured. Also, the apricot-date bars examined by Rehman et al. (2012) contained less Na (on average 231 mg kg^{-1}) than we determined. Despite being essential for humans, Na is harmful in larger amounts as it increases the risk of hypertension, occurring in 3.5%-4% of the children's population (Flynn et al. 2017). The diet of children contains excessive amounts of sodium (184.2% of the requirement) (Kwiecień et al. 2015) due to the fact that almost every foodstuff contains table salt and, additionally, salt is added to meals on the table (Surma et al. 2020). The Polish Society of Hypertension currently recommends that daily salt intake should not exceed 5 g (2 g Na) – Tykarski et al. (2019). It should be noted that every time the level of Na is increased by 100 mmol, 1 mmol Ca is excreted with urine (Blackwood et al. 2001), and every 1 g Na supplied to the body results in the excretion of 26 mg Ca with urine (Goluch-Koniuszy 2010), which is particularly alarming given the common Ca deficiency in children's diets (Kwiecień et al. 2015).

Iron

One milk slice serving, on average, supplied nearly 1 mg (0.8 mg) Fe (24.53 mg kg^{-1} ± 13.19), which covered 8% of the requirement (10 mg) of children aged 4-6 for that element (Table 4). The content of Fe in cereal bars in the study of Agbaje et al. (2014) ranged from 33.64 to 41.52 mg kg^{-1}, which is higher than we measured. Rehman et al. (2012) assayed even higher levels of Fe (on average 49.6 mg kg^{-1}) for dried fruit bars, while Padmashree et al. (2012) and Padmashree et al. (2013) observed levels lower than both milk slices, rice flakes cereal bars and dried fruit bars – on average, respectively, 9.46 mg Fe kg^{-1} (in high-protein cereal bars) and 6.31 mg Fe kg^{-1} (in flaxoat nutty bars). Zyśk et al. (2020) noted the insufficient coverage of the requirement for Fe in children aged 3 (6.94 mg ± 1.31) and 4-6 (7.09 mg ± 1.48). Insufficient intake of this element leads to anaemia, which can be particularly hazardous for pre-schoolers (Dymkowska-Malesa, Szparaga 2013). Fe deficiency can affect the school results of children at any age. Fe deficiency in a child's body results in reduced activity of brain enzymes, attention deficit, quick fatigue, inhibited mental development and learning disorders (Anjos et al. 2013).

Copper

One milk slice serving, on average, supplied slightly 0.1 mg (0.07 mg) Cu (2,188 mg kg^{-1} ± 0.832), which covered 18% of the requirement (0.4 mg) of children aged 4-6 for that element (Table 4). In the study of Agbaje et al. (2014), the content of Cu in rice flake cereal bars ranged from 11.86 to 13.73 mg kg^{-1}, which is five times higher than the value measured in our study, and which covers the Cu requirement of pre-schoolers. In the study of Zurita-Ortega et al. (2020), the content of Cu in two out of thirty-five dietetic cereal bars exceeded safe levels and was considered potentially toxic. The supply of Cu exceeded standard levels (more than double) in the diet of 3-year-olds (0.88 mg ± 0.20) and 4-6-olds (0.92 mg ± 0.21) in the study conducted by Zyśk et al. (2020), who also identified a statistically significant positive correlation between the level of cognitive development of children aged 4-6 and the intake of Cu with the diet. Cu deficiency can adversely affect brain function, and adequate intake of Cu positively affects children's cognitive functions (Anjos et al. 2013). However, excessive intake of this microelement can have a deleterious effect on cognitive processes. Zhou et al. (2015) observed that excessive concentration of Cu in the blood serum adversely affects the memory of school children.

Zinc

One milk slice serving, on average, supplied 0.3 mg Zn (8.95 mg kg^{-1} ± ± 2.44), which covered nearly 6% of the requirement (5 mg) of children aged 4-6 for that element (Table 4). The content of Zn in cereal bars in the study of Agbaje et al. (2014) ranged from 29.76 to 50.95 mg kg^{-1}, which is higher than we measured. Dried apricot-date bars also contained more Zn (on average 28.4 mg kg^{-1}) than the milk slices in our study (Rehman et al. 2012). In contrast, on average, high-protein cereal bars (Padmashree et al. 2012) and flaxoat nutty bars (Padmashree et al. 2013) contained 2.8 mg Zn kg^{-1} and 2.48 mg Zn kg^{-1}. The supply of Zn exceeded standard levels in the diet of 3-year-olds (6.14 mg ± 1.19) and 4-6-olds (6.38 mg ± 1.13) in the study conducted by Zyśk et al. (2020). These authors also found a positive correlation between the level of cognitive development and the intake of Zn by children aged 4-6. Zinc deficiency can impair children's cognitive processes and motor function and increase the risk of hyperactivity and depression (Anjos et al. 2013). Fuglestad et al. (2016) found that a deficiency of Zn is associated with memory impairment in children and affects their neurodevelopment.

Coverage of Ca requirement by milk slices and cow's milk

Milk slices are advertised as snacks rich in milk cream, ideal for consumption during playtime, between meals, and after school. Their packaging shows a jug of white liquid, and the list of ingredients and the front label mention milk, which all create associations with Ca. Figure 2 presents the content of Ca in 15 analysed bars. The values were compared with the content of Ca in one glass (250 ml) of cow's milk, covering 30% of the daily Ca requirement of a child aged 4-6 (Kunachowicz et al. 2020) and being a good source of Ca in the diet of children (Jarosz et al. 2020). The highest Ca levels were found in bars nos 4 and 7 (>60 mg/serving); however, compared with

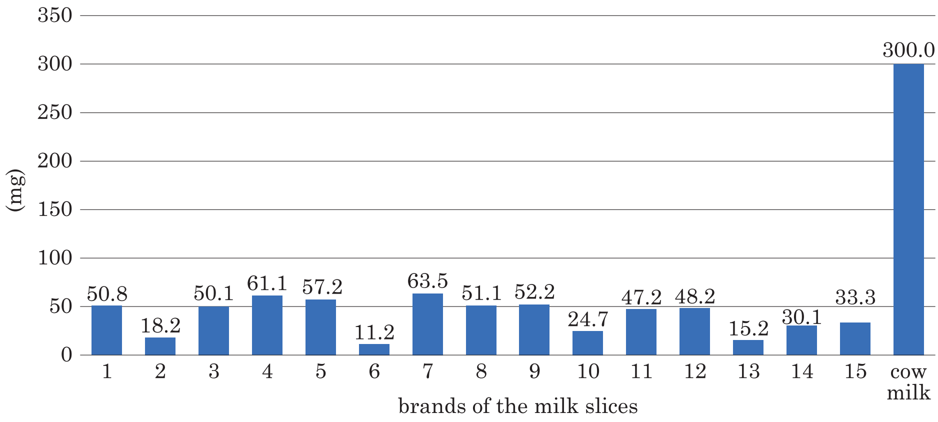

Fig 2. Comparison of Ca content in 1 package of milk slices with Ca content in 1 glass (250 ml) of cow's milk

milk, they corresponded to 20% of supplied Ca only. In contrast, the lowest Ca content was measured in bars 2, 6 and 13 (<20 mg/serving), which accounts for about 3-6% compared to the content of Ca in cow's milk. Differences in its content in milk slices and milk led to the conclusion that the analysed bars are not a good source of Ca in children's diets. In addition, milk slices are a source of added sugar in children's diets since they are rich in sugar and one milk slice supplies about 10 g of monosaccharides. The NHANES 2009-2014 study implies that the increasing consumption of added sugar also increases insufficient intake of Ca, Mg and vitamin D by children and young people in the USA (Fulgoni et al. 2019, 2020). Therefore, parents who wish to buy a valuable snack for their kids but have insufficient nutritional knowledge can misinterpret milk slice commercials and make incorrect food choices.

Coverage of demand for selected minerals with second breakfast and afternoon snack

Assuming five meals a day, the snack served to children should constitute 10% of the energy value of the diet in the second breakfast and 15% in the afternoon snack (Charzewska 2011). Milk slices are snacks in children's diets consumed mainly for second breakfast and afternoon snack during the day. Coverage of the demand for Ca, Mg, K, Na, Fe, Cu and Zn with milk slices as second breakfast and afternoon snack is presented in Table 5. A portion of a milk slice eaten for second breakfast and afternoon snack would cover the needs of a child aged 4-6 for Cu to the greatest extent (175% and 116.7%, respectively), and for Ca to the smallest extent (40.9% and 27.3%, respectively).

Table 5

Coverage of demand for selected minerals with second breakfast and afternoon snack

Minerals	Demand with second breakfast (10% of daily demand) (mg)	Coverage of demand with second breakfast (%)	Demand with afternoon snack (15% of daily demand) (mg)	Coverage of demand with afternoon snack (%)
Ca	100	40.9	150	27.3
Mg	13	125.4	19.5	83.6
K	110	106.9	165	71.3
Na	100	91.8	150	61.2
Fe	1.0	80.0	1.5	53.3
Cu	0.04	175	0.06	116.7
Zn	0.5	58.0	0.75	38.7

CONCLUSIONS

1. An average milk slice serving covered the requirement for Cu to the highest extent (17.9%) and that for Ca to the lowest extent (4.1%).

2. Milk slices are not a good source of minerals, particularly of Ca, in the diet of pre-schoolers; they cannot replace a serving of milk.

3. Correct supply of minerals significantly affects the child's psychosomatic development. Children should be encouraged to consume low-processed snacks, preferably wholegrain and bran-enriched ones since a serving of such cereals supplies more Ca and Mg to young bodies while keeping the Na supply low.

4. It is worth educating parents that the Dietary Reference Values placed on milk slices packaging applies to an average adult (8400 kJ/2000 kcal) and do not reflect the nutrients' demand of children, which may be misleading.

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