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ORIGINAL PAPER

THE CONTENT OF LEAD AND CADMIUM IN FRUIT-FLAVOURED YOGHURTS AND CREAM CHEESES*

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Abstract

Flavoured yoghurts and cream cheeses are usually promoted by the manufacturers as snacks for children and young people. An undeniable advantage of such products is the fact that they can be treated as convenience food because they have long expiry dates, they are ready to eat and available in packaging of various sizes. However, both milk and dairies can be a source of toxic metals, in particular Pb and Cd, for children. The research aimed to measure the level of Pb and Cd in fruit-flavoured yoghurts and cream cheeses. The analyses involved 83 products: 42 yoghurts and 41 cream cheeses. The products were split into 11 groups, depending on the used flavouring. The content of Cd and Pb was determined using the GF AAS method. In addition, the safety of fruit-flavoured yoghurts and cream cheeses was estimated for consumers aged 5 and 10. The analysed yoghurts contained on average 0.028 mg Pb and 0.008 mg Cd kg^{-1}, whereas the cream cheeses – on average 0.02 mg Pb and 0.017 mg kg^{-1} Cd. The values were lower than acceptable. The highest ($P < 0.05$) content of Pb was recorded in mixed flavour yoghurts, whereas as regards cream cheeses – in stone fruit flavoured products. The highest ($P < 0.05$) content of Cd was recorded in vanilla-flavoured yoghurts and in mixed flavour and strawberry-flavoured cream cheeses. For a child, having one cup of fruit-flavoured yoghurt is equivalent to a daily intake of max. 7% $BMDL_{01}$ Pb and max. 18.3% TWI Cd, whereas one cup of cream cheese – max. 28.5% $BMDL_{01}$ Pb and max. 33.5% TWI Cd. The presented results indicated that one cup of fruit-flavoured yoghurt and cream cheese was safe for consumers in terms of Cd and Pb content. However, it should be noted that products most eagerly chosen by children (strawberry, peach) had the highest content of Pb and/or Cd per 1 cup, which means that their frequent consumption can be associated with a risk of increased intake of such toxic metals.

Keywords: dairy products, Cd, Pb, safety.

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INTRODUCTION

Milk and dairy products are a very important source of protein, vitamins and minerals (Kłobukowski et al. 2014), in particular for children; a positive correlation was found between the correct balance and quality of a diet of pre-school children and the share of milk in such a diet (Ballew et al. 2000). Recommendations applicable in most countries indicate that children should consume ca. 500 - 550 mL of milk per day (Turlejska et al. 2006, Dror, Allen 2013). Milk can be partly replaced with dairy products (www.izz.pl) such as yoghurts and quarks.

Fermented milk drinks are products with higher nutritional and health value in comparison to milk (Cano-Sancho et al. 2015). The presence of live starter bacteria in yoghurts is a factor having influence on the therapeutic, preventive and dietary properties of yoghurts, which makes them a significant part of human diet in many countries of Europe. Yoghurts with added fruit are particularly popular, which in the first place is connected with their special flavour (Mesurolle et al. 2013, Całyniuk et al. 2015). Flavoured cream cheeses are usually promoted by the manufacturers as snacks for children and young people. Depending on a survey, from 31 up to 66 % of children at school age indicated that they liked such products very much (Bielaszka et al. 2014, Platta, Suszek-Namroży 2015). The main advantages of cream cheeses being the reason for including them in children's nutrition are the fact that they are a source of easily assimilable protein and many vitamins such as A, B1, B2, D, E and K, as well as cream, velvety consistency and pleasant taste (Sołowiej 2012). An undeniable advantage of yoghurts and cream cheeses is the fact that they can be treated as convenience food because they have long expiry dates, they are ready to eat and available in packaging of various sizes (Jesienkowska et al. 2014).

Milk and dairy products can be a source of toxic metals, including lead (Pb) and cadmium (Cd), for humans (król et al. 2012). The content of Pb and Cd in dairies depends, in the first place, on their content in milk, which in turn is determined by the environmental exposure of cows (Radzymińska et al. 2008). These metals, despite being present in food in small amounts, constitute a serious threat for the human organism and cause, among other conditions, anaemia, neurological lesions, memory impairment, renal failure, impaired iron absorption, osteoporosis, and cancer; in children Pb inhibits intellectual development and induces anaemia and rickets, while Cd impairs the function of the nervous system and disturbs bone formation processes (Zhai et al. 2015). Children are particularly exposed to the adverse effects of Pb and Cd due to a slower excretion process, lower body weight and also reduced immunity (Zhai et al. 2015).

The work aimed to investigate the content of Pb and Cd in products most eagerly consumed by children in Poland: fruit-flavoured yogurts and cream cheeses.

MATERIAL AND METHODS

Study material

Fruit-flavoured yoghurts and flavoured cream cheeses were purchased from retailers in Lublin in July 2014 ahead of their best-before dates. Until the analyses (for max. 10 days) the products were kept in a refrigerator at a temp. of ca. 4°C. The analyses involved 83 products: 42 yoghurts and 41 cream cheeses. The products were split into 11 groups, depending on the used flavouring: vanilla, strawberry, forest fruit (raspberries, blueberries, mixed forest fruits), stone fruit (peaches, apricots, sour cherries), exotic fruit (coconut, banana, lemon, pineapple) mixed fruit (two flavours: strawberry and wild strawberry, pineapple and coconut, strawberry and vanilla, peach and passion fruit, apple and vanilla, raspberries and vanilla), chocolate (Tables 1, 2).

Preparation of samples for analyses

Immediately before sampling, the products were mixed manually. Samples of approx. 20 g were taken from the products and then homogenized (with a Teflon pestle in a glass homogenizer). From each homogenized sample new samples of approx. 3 g were weighed in three replications. The procedure of preparing the samples for analysis was based on a scheme described in another work (Winiarska-Mieczan 2014): the samples were dried one by one at a temperature of 65°C for 24 h and then at 105°C for 24 h; the dried samples were dry mineralised in a muffle furnace at 450°C for 12 h using H_2O_2 as the oxidant; the resultant mineralisate was dissolved in 10 mL 1M HNO_3.

Chemical analyses

The content of Pb and Cd was determined by GF AAS in a Varian Spectr AA 880 (Santa Clara, CA, USA) including atomisation in a graphite furnace. The determination parameters:

Pb: wavelength 217 nm, lamp 10 mA, spectral band pass 1 nm, pure gas argon, LOD 0.003 mg kg^{-1}, LOQ 0.010 mg kg^{-1}, mean recovery rate 93%, deviation of duplicate 5.7%;

Cd: wavelength 228.8 nm, lamp 4 mA, spectral band pass 0.5 nm, pure gas argon, LOD 0.001 mg kg^{-1}, LOQ 0.004 mg kg^{-1}, mean recovery rate 96%, deviation of duplicate 4.9%.

The spectrometer was calibrated according to the Merck (Germany) standard containing 50 μg Pb and 2.5 μg Cd L^{-1}. Quality control of analytical measurements was performed using 1M HNO_3 (blank sample) and certified reference materials: BCR-063R (Skimmed Milk Powder, contained 18.5 μg Pb kg^{-1}) and IRMM-804 (Rice Flour, contained 1.61 mg Cd kg^{-1}).

Table 1

Characteristics of analysed yogurts

Flavour	Flavour addition (%)	Energy (kcal 100 g^{-1})	Portion size (g)	Country
Vanilla A	no data	122	115	Poland
Vanilla B	no data	112	65	Poland
Vanilla C	no data	112	125	Poland
Vanilla D	no data	83	150	Poland
Strawberry A	5.5	99	125	Poland
Strawberry B	9	98	150	Poland
Strawberry C	9	91	150	Poland
Strawberry D	10	95	125	Germany
Strawberry E	8.6	87	150	Poland
Strawberry F	9	92	150	Poland
Strawberry G	28	169	140	Czech Republic
Pineapple A	9	60	150	Poland
Pineapple B	4.5	43	115	Poland
Pineapple C	12	95	125	France
Lemon A	no data	88	150	France
Lemon B	3	131	150	Germany
Lemon C	1	70	200	Poland
Grapefruit	6.3	68	150	Poland
Peach A	15	94	125	Germany
Peach B	12	95	125	France
Apricot A	12	95	125	France
Apricot B	no data	96	65	Poland
Sour cherries A	9	100	150	Poland
Sour cherries B	9	63	150	Poland
Coconut	no data	88	100	France
Coconut	23	125	150	Germany
Pineapple-coconut	1.6	45	150	Poland
Strawberry-wild strawberry	9	100	150	Poland
Bilberries A	28	172	150	Czech Republic
Bilberies B	6.3	100	150	Poland
Billberies C	7	104	200	Lithuania
Raspberries A	5	31	150	Poland
Raspberries B	3.5	112	100	Poland
Raspberries C	9	100	150	Poland
Raspberries D	18	95	150	Czech Republic
Raspberries E	4.5	83	115	Poland
Fruits of the forest A	3.5	82	125	Poland
Fruits of the forest B	15	97	140	Poland
Banana A	9	95	50	UE
Banana B	15	93	125	Germany
Banana C	9	100	150	Poland
Banana D	15	97	100	France

Table 2

Characteristics of analysed cream cheeses

Flavour	Taste additive (%)	Energy (kcal 100 g $^{-1}$)	Portion size (g)	Country
Vanilla A	no data	165	150	Poland
Vanilla B	no data	162	150	Poland
Vanilla C	no data	no data	150	Poland
Vanilla D	0.02	122	175	Poland
Vanilla E	0.02	120	150	Poland
Vanilla F	no data	119	60	Poland
Vanilla G	no data	142	100	Poland
Vanilla H	no data	110	50	Poland
Vanilla I	no data	121	60	Poland
Vanilla J	no data	165	62	Poland
Strawberry A	4	125	140	Poland
Strawberry B	14	145	150	Poland
Strawberry C	no data	123	150	Poland
Strawberry D	5.6	132	140	Poland
Strawberry E	6.3	115	130	Poland
Strawberry F	6.8	117	165	Poland
Strawberry G	5	154	125	Poland
Strawberry H	3.3	125	80	Czech Republic
Fruits of the forest	5	147	140	Poland
Bilberry A	6.2	112	80	Poland
Bilberry B	4.6	110	140	Poland
Bilberry C	10	112	100	France
Peach A	5	115	135	Poland
Peach B	5.5	120	165	Poland
Sour cherries A	7.5	63	200	Germany
Sour cherries B	7	150	150	Poland
Sour cherries C	10.4	104	140	Poland
Strawberry-vanilla	no data	111	135	Poland
Peach-passion fruit	11	122	140	Poland
Apple-vanilla	5.6	117	150	Poland
Raspberries-vanilla	5.2	121	150	Poland
Banana A	4	110	50	Poland
Banana B	4	151	140	Poland
Banana C	6.1	106	50	Poland
Coconut A	no data	114	130	Poland
Coconut B	4.8	134	150	Poland
Coconut C	no data	120	140	Poland
Coconut D	5	121	100	France
Stracciatella A	no data	132	140	Poland
Stracciatella B	2.6	131	135	Poland
Chocolate	1.8	119	130	Poland

Calculation and statistical analysis

The results were compared with the Regulation of the Minister of Health of 13 January 2003 (Journal of Laws 2003), currently in force in Poland, according to which cottage cheese and milk desserts should not contain more than 0.2 mg Pb and 0.03 mg Cd kg^{-1} of the product. In addition, the content of Cd and Pb per one cup of the product was calculated. In the calculations, one serving was one cup of the product assuming that normally one eats a whole cup of yoghurt or cream cheese. Based on this information, the safety of fruit-flavoured yoghurts and cream cheeses was estimated for children aged 5 and 10. The following average body weight values were adopted: 19 kg for 5-year-old children and 34 kg for 10-year-old children (RÓŻDŻYŃSKA et al. 2013). The acceptable intake of Pb and Cd was determined based on the standards of EFSA (2012*a*,*b*): BMDL01 (Benchmark Dose Lower Confidence Limit) = 0.5 μg kg^{-1} body weight/day (3.5 μg kg^{-1} body weight/week) and TWI (Tolerable Weekly Intake) = 0.36 μg Cd kg^{-1} body weight/day (2.5 μg kg^{-1} body weight/week).

Reagents

Hydrogen peroxide H_2O_2 (analytical grade) and nitric acid HNO_3 (analytical grade) from POCH S.A. (Poland) were checked for possible trace contamination. Certified reference materials (BCR-063R Skimmed Milk Powder and IRMM-804 Rice Flour) were purchased from the Institute for Reference Materials and Measurements in Geel (Belgium).

RESULTS

In the presented studies, fruit-flavoured yoghurts contained on average 0.028 mg Pb kg^{-1} (range <LOQ – 0.141) – Table 3, whereas cream cheeses contained on average 0.02 mg Pb (range 0.001 – 0.032) – Table 4. In comparison to standards currently in force in Poland (Journal of Laws 2003) the values were lower than the threshold values; in yoghurts they were max. 7% (the highest content of Pb), whereas in cream cheeses up to 16% (for the maximum content of Pb). The analysed yoghurts contained on average 0.008 mg Cd kg^{-1} (<LOQ – 0.020), whereas cream cheeses – 0.017 mg kg^{-1} (range <LOQ – 0.027) – Tables 3, 4. Comparing the maximum values from own studies to standards currently in force in Poland (Journal of Laws 2003), the values were lower than acceptable values; for yoghurts they were max. 67% of the standard value, whereas for cream cheeses ca. 90% of the standard value.

The highest content of Pb was recorded in mixed flavour yoghurts (on average 0.14 mg kg^{-1}), then in stone fruit and exotic fruit flavoured yoghurts (0.009 - 0.01 mg kg^{-1}). Also, the highest content of Pb (on average 0.028 mg kg^{-1})

Table 3

Results of yogurt analyses

Specifiacation	*n*	Pb (mg kg^{-1})	Cd (mg kg^{-1})
Vanilla	4	0.002^{c} (0.001 – 0.004)	0.019^{a} (0.017 – 0.020)
Strawberry	7	0.002^{c} (<LOQ – 0.008)	0.008^{c} (<LOQ – 0.017)
Fruits of the forest	10	0.001^{d} (<LOQ – 0.003)	0.016^{b} (0.012 – 0.019)
Stone fruits	6	0.010^{b} (0.001 – 0.018)	0.005^{d} (<LOQ – 0.017)
Mixed taste	2	0.014^{a} (0.013 – 0.014)	0.003^{e} (<LOQ – 0.004)
Exotic fruits	13	0.009^{b} (<LOQ – 0.018)	0.003^{e} (<LOQ – 0.012)
Descriptive statistics			
Mean		0.028	0.008
Minimum		<LOQ	<LOQ
Maximum		0.014	0.020
Standard deviation		0.027	0.008
Number of samples < LOQ		5	8
Norms (Journal of Laws 2003)		0.2	0.03
Percent of norm		<LOQ - 7	<LOQ - 67

LOQ Pb = 0.010 mg kg^{-1}; LOQ Cd = 0.004 mg kg^{-1}; $^{a, b, c}$ – means with different superscripts in the same column differ significantly at $P < 0.05$ by the Duncan's test.

Table 4

Results of cream cheese analyses

Specifiacation	*n*	Pb (mg kg^{-1})	Cd (mg kg^{-1})
Vanilla	10	0.019^{c} (0.010 – 0.031)	0.013^{e} (<LOQ – 0.021)
Strawberry	8	0.017^{d} (0.013 – 0.023)	0.021^{ab} (0.012 – 0.027)
Fruits of the forest	4	0.023^{b} (0.019 – 0.027)	0.015^{d} (0.014 – 0.016)
Stone fruits	5	0.028^{a} (0.025 – 0.032)	0.015^{d} (0.013 – 0.015)
Mixed taste	4	0.023^{b} (0.017 – 0.029)	0.022^{a} (0.019 – 0.027)
Exotic fruits	7	0.017^{d} (0.014 – 0.020)	0.018^{c} (0.013 – 0.021)
Chocolate	3	0.023^{b} (0.021 – 0.025)	0.020^{b} (0.017 – 0.022)
Descriptive statistics			
Mean		0.020	0.017
Minimum		0.010	<LOQ
Maximum		0.032	0.027
Standard deviation		0.006	0.007
Number of samples < LOQ		0	1
Norms (Journal of Laws 2003)		0.2	0.03
Percent of norm		4.80 - 15.9	<LOQ - 90.4

LOQ Cd = 0.004 mg kg^{-1}; $^{a, b, c}$ – means with different superscripts in the same column differ significantly at $P < 0.05$ by the Duncan's test.

Table 5

The content of Cd and Pb in one cup of yoghurt and estimated weekly intake of Cd and Pb by children

Specification	Yogurts			Cream cheeses		
	n	Pb (µg)	Cd (µg)	*n*	Pb (µg)	Cd (µg)
Vanilla	4	0.351^{c}	2.912^{a}	10	2.055^{d}	1.652^{f}
Strawberry	7	0.362^{c}	1.314^{c}	8	2.552^{c}	3.114^{b}
Fruits of the forest	10	0.186^{d}	2.238^{b}	4	2.429^{c}	1.611^{f}
Stone fruits	6	1.503^{a}	0.733^{d}	5	3.890^{a}	1.995^{d}
Mixed taste	2	0.353^{c}	0.024^{f}	4	3.239^{b}	3.150^{a}
Exotic fruits	13	1.120^{b}	0.332^{e}	7	1.641^{e}	1.813^{e}
Chocolate	0	-	-	3	3.152^{b}	2.702^{c}
Mean		0.646	1.252		2.575	2.231
Intake from study products per 1 kg body weight per day (µg)*						
5-year-old children		0.034	0.066		0.143	0.121
10-year-old children		0.019	0.037		0.080	0.067
Tolerable intake (µg kg^{-1}) body weight per day **		$BMDL_{01}$ 0.5	TWI 0.36		$BMDL_{01}$ 0.5	TWI 0.36
Tolerable intake (%)						
5 years old children		6.800	18.30		28.51	33.49
10 years old children		3.801	10.23		15.93	18.72

Means with different superscripts in the same column differ significantly at $P < 0.05$ by the Duncan's test; * Based on consumption of 1 portion of yoghurts or cream cheeses per day, mean level of metals in products, and in a range of 19 - 34 kg (5- and 10-year-old children) body weight (RÓŻDŻYŃSKA et al. 2013); ** based on EFSA 2012*a*,*b*.

was recorded in cream cheeses containing stone fruits (peaches, sour cherries), while the lowest in strawberry-flavoured and exotic fruit-flavoured cream cheeses – on average 0.017 mg kg^{-1} of the product. On average, one cup of yoghurt contained ca. 0.6 μg Pb, whereas one cup of cream cheese – ca. 2.6 μg (Table 5). The highest ($P < 0.05$) content of Pb was recorded in one cup of both solid fruit flavoured yoghurts and cream cheeses, whereas the lowest in vanilla, strawberry and mixed flavour yoghurts and in exotic fruit flavoured cream cheeses.

The highest ($P < 0.05$) content of Cd was recorded in vanilla-flavoured yoghurts (on average 0.019 mg kg^{-1}) and in mixed flavour and strawberry--flavoured cream cheeses (on average 0.021 – 0.022 mg kg^{-1}) – Tables 3, 4. One cup of yoghurt contained on average ca. 1.25 μg Cd, whereas one cup of cream cheese – 2.23 μg Cd (Table 5). The highest ($P < 0.05$) content of Cd was recorded in one cup of vanilla-flavoured yoghurts (more than 2.9 μg) and in mixed flavour cream cheeses (on average 3.15 μg) and strawberry--flavoured cream cheeses (on average 3.114 μg).

In one cup of cream cheese the content of Cd was nearly twice and that of Pb four times higher in comparison to yoghurts (Table 6). One cup of

Table 6

Comparison of the average content of Cd and Pb per one cup of the analysed products

Pb (μg)	
Yogurts vs cream cheeses *	+ 399%
ANOVA *P*	0.003
Cd (μg)	
Yogurts vs cream cheeses *	+ 178%
ANOVA *P*	0.128

* The values for yogurts were assumed to be 100%.

fruit-flavoured yoghurt for a 5-year-old consumer is equivalent to less than 7% $BMDL_{01}$ Pb and 18.3% TWI Cd, whereas for a 10-year-old child the values are 3.8% $BMDL_{01}$ Pb and 10.2% TWI Cd (Table 5). The share of cream cheeses in supplying Pb assuming that one cup of cream cheese is consumed, is 28.5% $BMDL_{01}$ for 5-year-old children and ca. 16% $BMDL_{01}$ for 10-year-old children. For a 5-year-old consumer one cup of cream cheese a day will correspond to 33.5% TWI Cd, whereas for a 10-year-old child – 18.7% TWI (Table 5).

DISCUSSION

Among dairies, the basic source of toxic metals is milk. In turn, the content of such metals in milk is determined, in the first place, by environmen-

tal exposure of cows: complexes, formed by metals and organic matter, are assimilated by plants, which in turn are consumed by animals and penetrate into milk (van der Fels-Klerx et al. 2011). Studies into the content of Pb and Cd in milk and low-fat milk products available on the Polish market showed that milk products contained significantly more of these toxic metals than milk (Winiarska-Mieczan 2014). Furthermore, the studies found that fruit--flavoured yoghurts contained significantly more Cd than natural flavour products (natural yoghurts, yellow cheeses and cottage cheeses, kefir (kind of buttermilk). Studies carried out in Bangladesh showed that commercial yoghurts contained 0 - 0.016 mg Pb kg^{-1} (Shahriar et al. 2014). Studies into milk products in Romania showed that fruit-flavoured yoghurts contained more cadmium than natural yoghurts, on average 0.115 mg vs. 0.259 mg kg^{-1} (Dobrinas et al. 2010). Toth et al. (2015) demonstrated that fruit-flavoured yoghurts made in Slovakia contained max. 0.091 mg Pb and 0.005 - 0.039 mg Cd kg^{-1} of the product. Turkish yoghurts contained 0.045 - 0.061 mg Pb (Tarakçı, Dağ 2013), yoghurts from Egypt 0.039 mg Pb and 0.059 mg Cd (Ebn et al. 2009), Spain 0.01 - 0.09 mg Pb and 0.01 - 0.02 mg Cd (Cano--Sancho et al. 2015), whereas those in Saudi Arabia contained 0.025 mg Pb kg^{-1} (Al Othman 2010). The results of studies concerning the content of Pb and Cd in cream cheeses are less numerous. Tokuşoglu et al. (2004) demonstrated that Turkish cream cheeses contained 0.69 mg Pb and 0.335 mg Cd kg^{-1}, whereas own studies by the authors of this work found that cream cheeses on average contained 0.020 mg Pb and 0.017 mg Cd kg^{-1}. However, it should be emphasised that studies carried out both in Poland and in other countries show that milk and dairy products are safe for consumers in terms of toxic metals content (Gabryszak et al. 2008, Starska et al. 2011). The present study also shows that the analysed fruit-flavoured yoghurts and cream cheeses are safe for consumers in terms of Pb and Cd content, because they do not contain these toxic metals in amounts exceeding standards applicable in Poland (Journal of Laws 2003).

The current research showed that one cup of stone fruit flavoured yoghurts and cream cheeses (peach, apricot, sour cherries) contained the most Pb, whereas the highest content of Cd was recorded in vanilla yoghurts and strawberry-flavoured and mixed flavour (strawberry and vanilla, peach and passion fruit, apple and vanilla, raspberry and vanilla) cream cheeses. The results are disturbing because it was found that strawberry and peach were flavours of milk products and desserts most eagerly chosen by children (Cornwell, McAlister 2011, Mennella 2014). Strawberry, peach and vanilla--flavoured cream cheeses are most frequently bought in Poland (Sołowiej 2012). Surveys carried out among pre-school children showed that strawberry was one of their favourite fruits, apart from banana and apple (Winiarska--Mieczan et al. 2015).

The present study showed that one cup of fruit-flavoured yoghurt or cream cheese would correspond to Pb intake of max. 18.3% $BMDL_{01}$ (yoghurt, 5-year-old children) and Cd in the maximum amount of 33.5% TWI (cream

cheese, 5-year-old children) per day. These values are safe and they do not exceed the standards of EFSA (2012*a*,*b*). However, considering that other foodstuffs are also the source of Pb and Cd, the consumption of fruit--flavoured yoghurts and cream cheeses by children should be reduced to one cup a week. Instead of ready products, children should be given natural flavour milk products containing less Pb and Cd (Dobrinas et al. 2010, Winiarska-Mieczan 2014). They can be mixed with fresh fruit from a reliable source.

CONCLUSIONS

The present study indicated that one cup of fruit-flavoured yoghurt or cream cheese was safe for children in terms of Cd and Pb content. However, it should be noted that products most eagerly chosen by children (strawberry, peach) had the highest content of Pb and/or Cd per one cup, which means that their frequent consumption can be associated with a risk of increased intake of such toxic metals.

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