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ASSESSMENT OF THE RISK OF EXPOSURE TO CADMIUM AND LEAD AS A RESULT OF THE CONSUMPTION OF LOW-FAT DAIRY PRODUCTS BY EXPECTANT AND LACTATING WOMEN

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ABSTRACT

Background. The study aimed to assess the risk related to consumption of low-fat dairy products by expectant and lactating women.
Material and methods. A survey was used to verify the popularity of such products among expectant and lactating women and then the content of Cd and Pb in low-fat dairy products was determined.
Results. In the group of expectant women consuming dairy products, nearly 93% of the respondents consumed low-fat dairy products, while among lactating women the result was 90%. Both the expectant and lactating women mostly preferred milk and fruit yoghurt. It was found that the studied low-fat products did not contain more Cd and Pb than their standard counterparts.
Conclusion. Taking into account the intake of low-fat milk and dairy products declared by respondents, such products must be regarded safe in terms of Cd and Pb content. The maximum supply of Cd and Pb for both groups of women did not exceed 3% TWI and 2% $BMDL_{10}$.

Key words: lactating women, expectant women, low-fat dairy products, Cd, Pb, risk of exposure

INTRODUCTION

In Poland and in other European countries the energy value of a diet is normally higher than recommended by nutrition guidelines, which results in an increased percentage of overweight and obese people [Jarosz and Rychlik 2009]. As a consequence, for health reasons, it is necessary to reduce the consumption of high energy foods. Therefore, both consumers and dieticians have been increasingly interested in low-fat foods [Pirozzo et al. 2003]. Low-fat products available for sale are usually the counterparts of traditional food products. Studies show that low energy food products are very popular, in particular among young women [Flaczyk et al. 2006]. They most frequently choose dairy products, and especially yoghurts [Flaczyk et al. 2006]. Dairy products form an important element of the daily diets of Polish consumers with regard to high nutritional value, and in particular the content of complete protein and calcium [Górska-Warsewicz 2005]. Expectant women should consume at least 3-4 servings of 200 ml of milk a day [Waszkowiak et al. 2010], while lactating women – 3 servings [Wojtyła et al. 2011]. This product can be partially replaced by other dairy products [Waszkowiak et al. 2010]. Studies by Hyżyk and Sokalska

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[2011] showed that in Poland pregnant women most frequently consume milk, yoghurts and cheese. The available literature does not contain any data regarding the popularity of low-fat dairy products in diets of expectant and lactating women, but supposedly women in those periods of their lives consume low-calorie products to prevent excessive weight gain. In European countries low-fat dairy products are also recommended during pregnancy and in the period of lactation [Brantsæter et al. 2012, WHO 2001].

Numerous data suggests that milk and dairy products can be a source of toxic metals for humans [Birghila et al. 2008, Starska et al. 2011]. The content of metals in milk depends primarily on the environmental 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 [Fels-Klerx et al. 2011]. The literature available both in Poland and throughout the world lacks the results of studies concerning the content of toxic metals in low-fat products. Considering that such products are very popular and can also be consumed by particularly vulnerable consumers, such as expectant and lactating women, they must be monitored for their toxic metals content – most of all cadmium and lead. The dynamically developing nervous system of the foetus and infant is most exposed to these metals which also disturb bone-forming processes [Sughis et al. 2011], can inhibit intellectual development and cause anaemia and rickets [D'Souza et al. 2003]. Significantly, a positive correlation between the concentration of toxic metals in children and the occurrence of autism has been observed [Bradstreet et al. 2003]. However, mother's milk can also be a source of heavy metals for an infant. The content of these elements in breast milk reflects the level of environmental pollution and the woman's diet [Gundacker et al. 2002, Nishijo et al. 2002]. The content of metals in food most often consumed by lactating women must be continuously monitored.

The study aimed to: 1) assess the popularity of low-fat dairy products among expectant and lactating women; 2) check whether they could be a significant source of cadmium and/or lead since the author's survey demonstrated that such products were consumed by the definite majority of women.

MATERIAL AND METHODS

Survey

The survey was carried out in Lublin, Świętokrzyskie and Łódź Voivodeships from May to June 2011. Data was collected from 674 expectant women (255 from Lublin Voivodeship, 235 from Świętokrzyskie Voivodeship and 184 from Łódź Voivodeship) and 725 lactating women (326 from Lublin Voivodeship, 280 from Świętokrzyskie Voivodeship and 119 from Łódź Voivodeship). The respondents were divided into 5 age groups: younger than 20, 20-25, 26-30, 31-35 and above 35 years of age (Table 1). An identical survey questionnaire for both groups of women consisted of 18 questions, mostly single-choice, but there were also multiple-choice questions. The questions referred to consumption of low-fat dairy products, among other things, the reasons for choosing this type of products and their preferred types. In addition, over seven successive days the women had to complete a table giving the size of servings of low-fat dairy products consumed.

Study material

The content of Cd and Pb was studied in 186 low-fat dairy products: 36 natural yoghurts, 41 fruit yoghurts, 12 kefirs, 38 quark cheeses, 14 yellow cheeses and 45 samples of pasteurised cow's milk (Table 2). The products were bought in food stores in Lublin, Kielce and Łódź in September and October 2012, still within their shelf-life. The samples were frozen at a temperature of –18°C until chemical analyses.

Chemical analyses

Thawed at room temperature, the samples were mixed manually. Afterwards, the samples of different consistency (quark cheeses and yellow cheeses and fruit yoghurts) were homogenised. Every sample was taken in three repetitions: with a volume of ca. 3 ml (milk) or weight of ca. 3 g (other products). The samples, dried at 65°C over the following 24 h and then at 105°C over 24 h, underwent combined mineralisation in a muffle furnace at a temperature of 450°C over 12 h, using hydrogen peroxide as the oxidant. The resulting ash was dissolved in 1 M HNO_3.

The content of Cd and Pb was determined by GF AAS technique in a Varian Spectr AA 880 apparatus

Table 1. Profile of the analysed population of women

	Age of the mothers, years										Total	
	< 20		20-25		26-30		31-35		> 35			
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Expectant women	112		123		151		165		123		674	
BMI												
Correct mass	107	96	117	95	141	93	158	96	119	97	642	95
Overweight	5	4	6	5	10	7	7	4	4	3	32	5
Eating dairy products	112	100	121	98	150	99	161	98	118	96	662	98
No dairy products consumption	0	0	2	2	1	1	4	2	5	4	12	2
Eating low-fat dairy products	110	98*	119	98*	139	93*	140	87*	110	93*	618	93
Once a week or occasionally	44	40**	38	32**	48	35**	51	36**	46	42**	227	37
Several times a week	35	32**	47	39**	45	32**	54	39**	34	31**	215	35
Every day	31	28**	34	29**	46	33**	35	25**	30	27**	176	28
3-4 times daily	13	42***	17	50***	25	54***	19	54***	22	73***	96	55
1-2 times daily	18	58***	17	50***	21	46***	16	46***	8	27***	80	45
No low-fat dairy products consumption	2	2*	2	2*	11	7*	21	13*	8	7*	44	7
Lactating women	123	100	151	100	153	100	146	100	152	100	725	100
BMI												
Correct mass	101	82	125	83	122	80	122	84	129	84	599	83
Overweight	22	18	26	17	31	20	24	16	23	16	126	17
Eating dairy products	93	76	105	70	96	63	104	71	92	61	490	68
No dairy products consumption	30	24	46	30	57	37	42	29	60	39	235	32
Eating low-fat milk products	74	80*	93	89*	73	76*	62	60*	85	92*	387	79
Once a week or occasionally	30	40**	34	37**	15	21**	15	24**	20	24**	114	29
Several times a week	25	34**	20	21**	39	53**	34	55**	28	33**	146	39
Every day	19	26**	39	42**	19	26**	13	21**	37	43**	127	32
3-4 times daily	8	42***	22	56***	10	53***	7	54***	24	65***	71	56
1-2 times daily	11	58***	17	44***	9	47***	6	46***	13	35***	56	44
No low-fat dairy products consumption	19	20*	12	11*	23	24*	42	40*	7	8*	103	21

*Total women eating dairy products was assumed as 100%.
**Total women eating low-fat dairy products was assumed as 100%.
***Total women eating low-fat dairy products every day was assumed as 100%.

Table 2. Characteristics of analysed low-fat dairy products

	Natural yoghurt	Fruit yoghurt	Kefir	Quark cheese	Yellow cheese	Milk
n	56	76	16	38	14	65
Made in						
Poland	31	27	16	14	7	35
France	20	22	0	8	5	18
Germany	5	19	0	12	1	10
Czech Republic	0	8	0	4	1	2
"Light" annotation						
Yes	44	62	10	38	14	0
No	12	14	6	0	0	65
0% fat products	12	14	8*	0	0	65

*Some products were labelled as 0% fat + "light".

(atomisation in a graphite furnace, the Zeeman background correction, pure gas – argon). The content of Cd was determined at λ = 228.8 nm, with 4 mA and 0.5 nm spectral band pass (LOD 0.01 mg/kg, LOQ 0.02 mg/kg). The deviation of duplicate measurement was below 5.3%, the mean recovery rate was 96%. The content of lead was determined at λ = 217.0 nm, with 10 mA and 1 nm spectral band pass (LOD – 0.209 mg/kg, LOQ – 0.419 mg/kg). The deviation of duplicate measurement was below 5%, the mean recovery rate – 95%. In order to make the calibration line, standard solutions of Cd and Pb were procured from Merck (Germany). Quality control of analytical measurements was performed using blank samples and certified reference materials: IRMM-804 Rice Flour (Cd) and BCR-063R Skimmed Milk Powder (Pb).

Calculation and statistical analysis

The content of Cd and Pb in cow's milk was calculated per 100 ml, while in other samples – per 100 g of the product. Based on the declared maximum weekly intake of respective groups of products by expectant and lactating women (Table 3), the daily supply of Cd and Pb was calculated. Based on the daily supply of Cd and Pb in the studied products, the TWI (Tolerable Weekly Intake) percentage was calculated for Cd and $BMDL_{10}$ (Benchmark Dose Lower Confidence Limit) for Pb, assuming respectively 2.5 μg/kg of body weight/week [EFSA 2012 a] and 4.4 μg/kg of body weight/week (0.63 μg/kg of body weight/day) [EFSA 2012 b]. The average body weight declared by the respondents – 73 kg during pregnancy and 60 kg during lactation – was used in the calculation. The results were analysed with the use of STATISTICA 6.0 software.

RESULTS

Expectant women

On average, 98% of expectant women taking part in the study consumed dairy products, out of which nearly 93% of respondents admitted choosing low-fat dairy products (Table 1). Nearly all women younger than 20 and aged 20-25 declared they consumed low-fat products. Women aged 31-35 (87% of the respondents) least frequently declared choosing such products. On average, 28% of the respondents consumed low-fat products every day, and 55% declared consuming 3-4 servings per day. Expectant women consumed such products primarily in order to prevent excessive weight gain (94% of answers) and due to their favoured taste (indicated by 55%; Fig. 1). A few other answers mentioned commercials, common trends and attractive packaging. Regardless of their age, women most often

Table 3. Results of low-fat dairy products analysis

	Natural yoghurt	Fruit yoghurt	Kefir	Quark cheese	Yellow cheese	Milk
n	36	41	12	38	14	35
Cd, µg/100 g						
Mean	0.155	0.556	0.150	0.267	0.308	0.093
Minimum	ND	ND	ND	0.097	0.017	ND
Maximum	0.237	1.132	0.094	0.783	0.968	0.994
Median	0.071	0.567	0.560	0.189	0.270	0.600
SD	0.109	0.089	0.119	0.087	0.092	0.130
SEM	0.317	0.218	0.292	0.384	0.487	0.652
Variance analysis	0.503	0.474	2.953	1.182	1.421	0.277
Percentile						
90%	0.000	0.648	0.064	0.177	0.050	0.073
10%	0.409	0.204	0.185	0.126	0.249	0.787
Pb, µg/100 g						
Mean	0.535	0.651	0.533	0.791	0.942	0.419
Minimum	ND	ND	0.009	0.329	ND	ND
Maximum	0.859	0.791	0.644	0.954	1.413	0.649
Median	0.050	0.129	0.030	0.068	0.065	0.013
SD	0.059	0.104	0.017	0.064	0.011	0.039
SEM	0.160	0.033	0.038	0.341	0.158	0.127
Variance analysis	0.129	0.011	0.004	0.929	1.595	0.048
Percentile						
90%	0.039	0.012	0.421	1.090	1.305	0.559
10%	0.748	0.690	0.524	0.456	0.158	0.079

ND – not detectable, SD – standard deviation, SEM – standard error of the means.

declared choosing fruit yoghurts. Also, products such as milk and quark cheese were very popular (Fig. 2). Women who did not consume dairy products (2%) claimed they did not like the taste of this food.

Lactating women

On average, 68% of lactating women declared that they consumed dairy products (Table 1). In this group, low-fat products were consumed by 90% of women aged 20-25 and over 35 years of age, including 40% women eating such products every day. In the whole studied population, 79% of the respondents consumed low-fat products, including 32% of women consuming them every day (56%, 3-4 servings per day). Most frequently, the reason for consuming such products was the intention to lose weight (97% of answers) and favoured taste (65%) (Fig. 1). The women preferred fruit yoghurts, quark cheese and milk (Fig. 2). Women, who did not consume dairy products (32% of the respondents) pointed exclusively to the risk of cow's

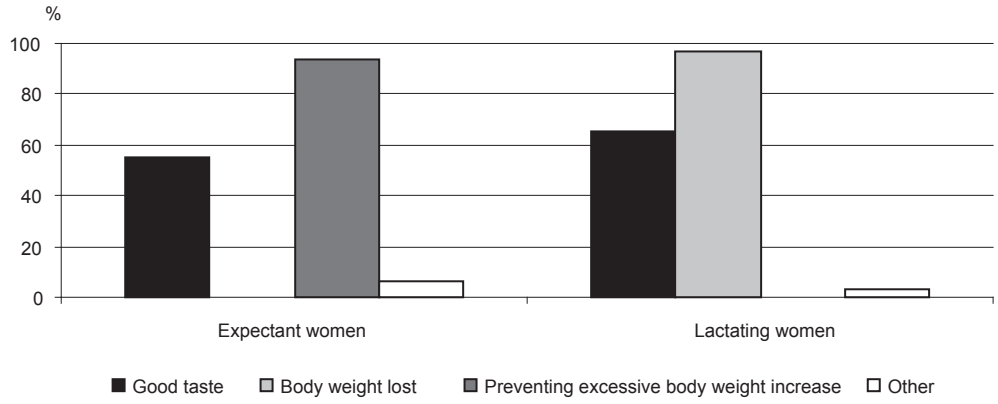

Fig. 1. Reasons for eating low-fat dairy products

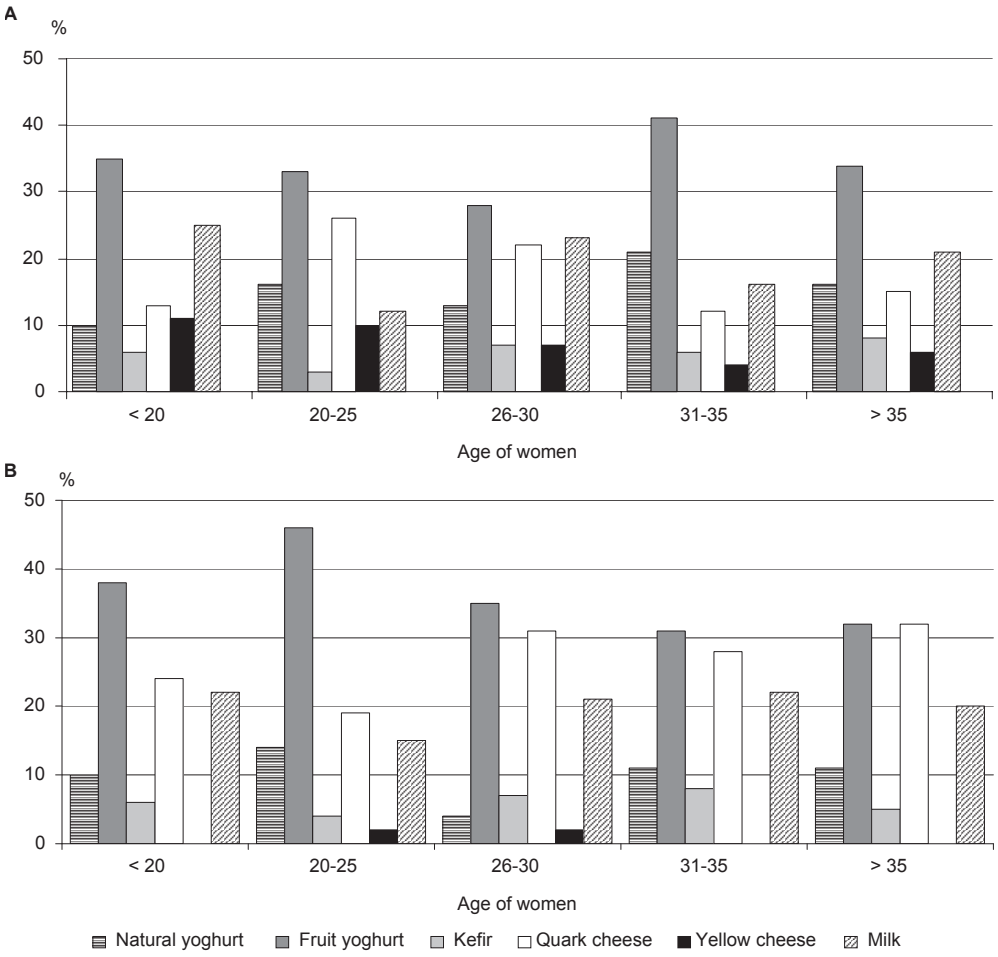

Fig. 2. Eating dairy low-fat products by expectant (A) and lactating (B) women

milk protein allergy occurring in the infant or were themselves allergic to cow's milk.

Content of Cd and Pb in low-fat dairy products

Table 3 presents the content of Cd and Pb in the studied low-fat dairy products. The highest content of Cd was found in fruit yoghurt – more than 0.5 μg/100 g of fresh weight, and in quark cheese and yellow cheese – about 0.3 μg/100 g. The least Cd was found in natural yoghurt (ca. 0.15 μg/100 g) and milk (less than 0.1 μg/100 g). The highest content of Pb was identified in quark cheese (0.79 μg/100 g) and yellow cheese (1.43 μg/100 g), while the least Pb was found in milk (ca. 0.42 μg/100 g). The safest products in terms of the content of both toxic metals were natural yoghurt and milk.

Intake of Cd and Pb with low-fat dairy products

The weekly supply of metals was calculated (Table 4) taking into account the weekly intake of the studied products, as declared by the respondents, and the average content of Cd and Pb in such products (determined by chemical methods). The maximum intake of products declared by both expectant and lactating women was used to assess the risk. It was found that the intake of the studied low-fat dairy products would not cause the tolerable safe intake level of Cd and Pb to be exceeded. The least amount of Cd is supplied with kefir (for expectant women it is 0.17% TWI, and for lactating women – 0.31% TWI) and yellow cheese (0.17% TWI for expectant women and 0.41% TWI for lactating women). The highest amount of Cd can be supplied to both expectant and lactating women with fruit yoghurt (ca. 2.3% TWI and 3% TWI, respectively), while to lactating women – fruit yoghurt and quark cheese (more than 8% TWI). The highest% $BMDL_{10}$ of Pb in both groups of women was identified in the case of fruit yoghurt consumption (ca. 1.5-2.0%), and the lowest in the case of yellow cheese (ca. 0.3% – expectant women and 0.7% – lactating women) and kefir (0.3% – expectant women and 0.6% – lactating women).

Table 4. Maximum weekly consumption of dairy low-fat products and Cd and Pb intake

	Expectant women						Lactating women					
	weekly consumption of products[a] g		maximum weekly intake[b] μg		% TWI[c]	% $BMDL_{10}$[c]	weekly consumption of products[a] g		maximum weekly intake[b] μg		% TWI[d]	% $BMDL_{10}$[d]
	maximum	mean	Cd	Pb			maximum	mean	Cd	Pb		
Natural yoghurt	400	150	0.62	2.14	0.34	0.67	500	250	0.78	2.68	0.52	1.01
Fruit yoghurt	750	350	4.17	4.88	2.28	1.52	820	350	4.56	5.34	3.00	2.02
Kefir	200	100	0.31	1.07	0.17	0.33	300	200	0.46	1.60	0.31	0.61
Quark cheese	150	100	0.40	1.19	0.22	0.37	300	175	0.80	2.37	0.53	0.90
Yellow cheese	100	100	0.31	0.94	0.17	0.29	200	100	0.62	1.88	0.41	0.71
Milk	1 000	650	0.93	4.19	0.62	1.30	1 000	500	0.93	4.19	0.62	1.59

[a]On the basis of the questionnaire survey.
[b]Calculated on the basis of the maximum consumption of products and mean level of Cd and Pb.
[c]Mean expectant women body weight was assumed as 73 kg.
[d]Mean lactating women body weight was assumed as 60 kg.
TWI – Tolerable Weekly Intake for Cd was determined at 2.5 μg/kg of body weight/week [EFSA 2012 a].
$BDML_{10}$ – Benchmark Dose Lower Confidence Limit for Pb was determined at 0.50 μg/kg of body weight per day [EFSA 2012 b].

DISCUSSION

Milk and dairy products should be consumed by expectant and lactating women mostly because such products are the fundamental and a very good source of calcium both for the woman and the baby [Waszkowiak et al. 2010]. Expectant and lactating women have an increased requirement of calcium [Sobczak and Jabłoński 2007]. Laskey et al. [1998] demonstrated that already after 3 months of lactation the level of calcium in the bones of women decreases, which is connected with the penetration of this component into milk. Thus, the intake of calcium and Vit. D, both with food and food supplements, should be increased. Studies by Bachanek and Nakonieczna-Rudnicka [2009] showed that 92% of expectant women declared they regularly consumed dairy products. According to Godala et al. [2012] only less than 2% of expectant inhabitants of Łódź did not consume milk and dairy products. Similar effects were observed by Wojtyła et al. [2011]. According to the author's own studies, on average 98% of expectant women and 68% of lactating women declared that they consumed milk and dairy products, including more than 90% of expectant women and nearly 80% of lactating women consuming low-fat products. Expectant and lactating women consumed these products due to their reduced energy value, thus in order to prevent excessive weight gain. The studies revealed a close relationship between consuming considerable amounts of full-fat dairy products and excessive BMI, while consuming low-fat dairy products had the opposite effect [Snijder et al. 2007, Beydoun et al. 2008]. In addition, dairy products are one of the fundamental sources of unsaturated trans fatty acids in the human diet [Combe et al. 2000] which are particularly hazardous for the foetus and infants [Jamioł-Milc et al. 2010]; thus, partial removal of fat simultaneously reduces the amount of trans acids.

Fat is the carrier of taste [Sasaki et al. 2007], so products from which fat was partially or wholly removed are usually characterised by weaker sensory values compared to their traditional counterparts. Studies by Jaworska [2007] showed that the level of acceptance of low-fat quark cheese among consumers was significantly lower. Also, Kaminarides et al. [2007] found that yoghurts produced from low-fat milk were characterised by weaker organoleptic properties than yoghurts produced from milk containing more fat. In the author's survey 55% of expectant women and 65% of lactating women claimed that low-fat products have a very favourable taste, not worse than that of traditional dairy products.

The most popular dairy products among different groups of people are cow's milk and yoghurts [Waszkowiak et al. 2010, Winiarska-Mieczan et al. 2007]. Also, the author's survey showed that both expectant and lactating women mostly preferred milk and fruit yoghurts. The eagerness to consume yoghurts was probably a result of their taste but it can be also attributed to the fact that they are carry-away foods which can be easily taken, for example, to work or for a walk. Yoghurts, which are fermented products, reduce the absorption of cholesterol and increase the bioactivity of calcium, which is better absorbed in an acidic environment [Pfeuffer and Schrezenmeir 2007].

It was found that the studied low-fat products did not contain more Cd and Pb than their standard counterparts from Poland and other countries (Fig. 3). The literature available both in Poland and throughout the world lacks the results of studies concerning the content of heavy metals in low-fat products. However, Enb et all. [2009] found that in processed cow's milk and buffalo milk containing more fat (butter, cream) the concentration of Cd and Pb was higher than in products containing less fat (yoghurt, milk). Opposite results were obtained by Radzymińska et al. [2008], who claimed that the smallest content of Cd and Pb was found in butter. However, the results obtained by the above-quoted authors are not sufficient to determine a relationship between the content of fat in foodstuffs and the content of toxic metal in them. Studies to be carried by our team in the future will compare the content of toxic metals in low-fat dairy products and with that in their traditional counterparts. The author's own studies revealed that quark cheese and yellow cheese contained the highest amount of Pb. The findings of Starska et al. [2011], who studied products with standard fat content, were similar. In the author's own studies the safest products in terms of the content of these metals were natural yoghurt and pasteurised milk. The studies involving Romanian products with a standard content of fat, carried out by Dobrinas et al. [2010], revealed that the lowest amount of Cd and Pb was contained in pasteurised

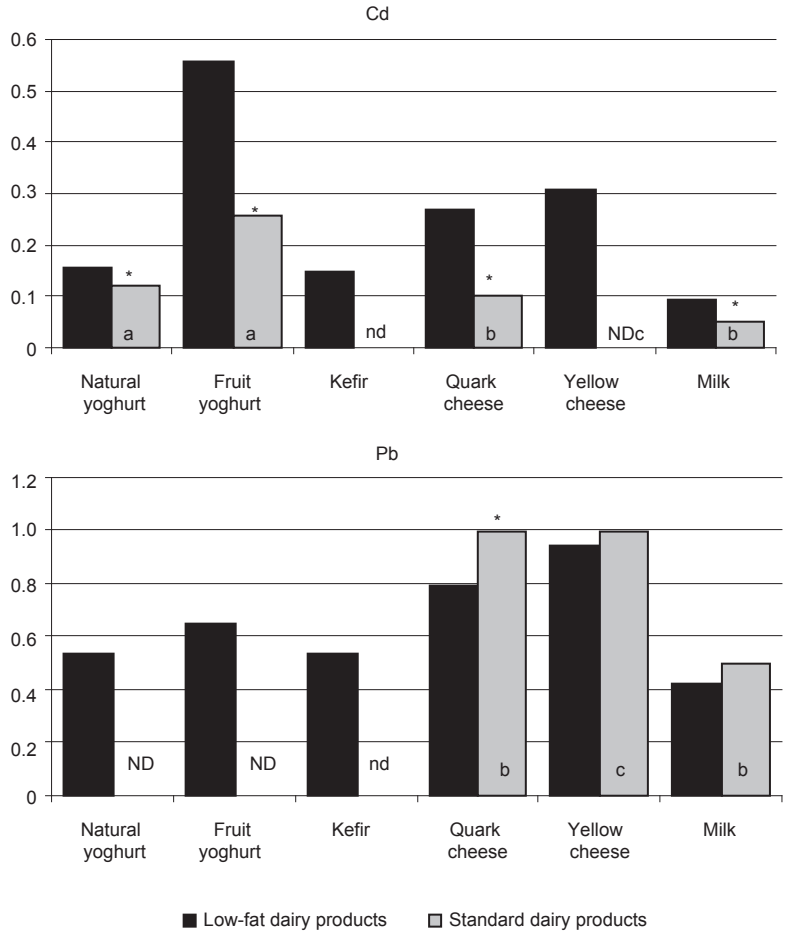

Fig. 3. Comparison of the concentrations of Cd and Pb in low-fat (this study) and standard dairy products, μg/100 g: a – Dobrinas et al. 2010, b – Starska et al. 2011, c – Szkoda and Żmudzki 1996; ND – not detectable, nd – no data; ∗ – significant versus low-fat dairy products ($P < 0.05$)

milk, whereas fruit yoghurt contained more cadmium than natural yoghurt (on average 0.115 mg vs 0.259 mg/kg). Polish studies showed that milk and dairy products are safe for consumers in terms of toxic metals content [Starska et al. 2011, Gabryszuk et al. 2008].

CONCLUSION

Based on the author's own findings, it can be claimed that the studied low-fat products did not contain more Cd and Pb than their standard counterparts. Taking into account the intake of low-fat milk and dairy products declared by respondents, such products must be regarded as safe in terms of Cd and Pb content. The maximum supply of Cd for both groups of women did not exceed 3% TWI, while that of Pb – 2% $BMDL_{10}$. Dairy products, and mostly low-fat products, should be promoted among expectant and lactating women. At the same time, it must be remembered that defatted dairy products are completely devoid of fat, so they also lack lipophilic vitamins, mostly vitamin D which is responsible for the correct intestinal absorption of calcium [Sunyecz 2008]. Conventional wisdom should not equate low-fat products and defatted products.

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OSZACOWANIE RYZYKA NARAŻENIA NA KADM I OŁÓW KOBIET CIĘŻARNYCH I LAKTUJĄCYCH W WYNIKU SPOŻYWANIA PRODUKTÓW MLECZNYCH O OBNIŻONEJ ZAWARTOŚCI TŁUSZCZU

STRESZCZENIE

Wstęp. Celem badań było oszacowanie ryzyka związanego ze spożywaniem produktów mlecznych o zredukowanej zawartości tłuszczu przez kobiety w okresie ciąży i laktacji.

Materiał i metody. Metodą ankietową sprawdzono popularność tych produktów wśród kobiet ciężarnych i laktujących, a następnie zbadano zawartość Cd i Pb w produktach nabiałowych o obniżonej zawartości tłuszczu.

Wyniki. W grupie kobiet ciężarnych spożywających nabiał produkty mleczne o obniżonej zawartości tłuszczu spożywało niemal 93% respondentek, wśród kobiet laktujących odsetek sięgał 90%. Mleko oraz jogurty owocowe były najchętniej wybierane przez kobiety zarówno ciężarne, jak i laktujące. Stwierdzono, że badane produkty o obniżonej zawartości tłuszczu nie zawierały więcej Cd i Pb niż odpowiednie produkty standardowe.

Wnioski. Biorąc pod uwagę deklarowane przez respondentki spożycie mleka oraz produktów mlecznych o zredukowanej zawartości tłuszczu, należy uznać je za bezpieczne pod względem zawartości Cd i Pb. Maksymalna podaż Cd i Pb w obu grupach kobiet nie przekraczała 3% TWI oraz 2% $BMDL_{10}$.

Słowa kluczowe: kobiety laktujące, kobiety ciężarne, produkty mleczne niskotłuszczowe, Cd, Pb, narażenie

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