Bull. Environm. Contam. Toxicol. 29, 658–664 (1982)

Transfer of Lead and Cadmium from Cow Milk to Butter

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The disturbances that such heavy metals as lead, cadmium and mercury may cause in an organism have been known in the form of occupational risks of workers handling such substances. Today, as environmental pollution caused by such heavy metals is becoming a more serious problem, it has become a major task to ascertain what kind of ill effects chronic exposure to these metals through the atmosphere and food have on human health. Itai-itai disease and Minamata disease, which occurred in Japan as a result of consumption of food contaminated with cadmium and mercury are good examples of these problems. Because of these occurrences, detailed reports have already been made regarding the concentrations of heavy metals in the atmosphere [YAMANE et al. 1973, COULSTON & KORTE 1975] as well as in foods [HOSOGAI & OKADA 1977, SUGIYAMA 1981] that are consumed daily and processed foods [KAWARAYA et al. 1978]. With regard to processed foods made from fish and livestock, it is necessary to ascertain to what extent the heavy metals that have been accumulated in the bodies of the animals, that is, biologically concentrated through the food chain, have been transferred. This kind of study has not yet been reported.

The authors [HAYASHI et al. 1980] earlier reported on the difference in the way lead and cadmium are transferred from raw milk to dairy products, in this case, cheese. In this study, transfer of lead and cadmium into butter and other dairy products produced in the process of making butter were studied and compared.

MATERIALS AND METHODS

The fresh milk purchased from a major dairy products company was adjusted so that lead (Pb) as lead acetate and cadmium (Cd) as cadmium acetate would have the concentration levels of 1, 10 and 50 ppm. Using 1,000 ml of the milk thus contaminated with Pb and Cd, butter was produced. The process by which the butter was made is outlined in Fig. 1. The amounts of butter and other dairy products produced are shown in Table 1. The but-

0007-4861/82/0029-0658 $01.40

ter was cleansed twice with about 50 ml of distilled water. When produced in a factory, butter is compressed into a shape after cleansing and packed, but these operations were eliminated in this study. Three samples were collected from each dairy product for Pb and Cd. The samples were slowly dissolved at low heat in 2 ml of 63% HNO_3, and carefully evaporated, and then 2 ml of 60% $HClO_4$ was added and heated on a hot plate until white ash was obtained. The ashed samples were dissolved in dilute nitric acid. The analysis of Pb and Cd was carried out by atomic absorption spectrophotometry.

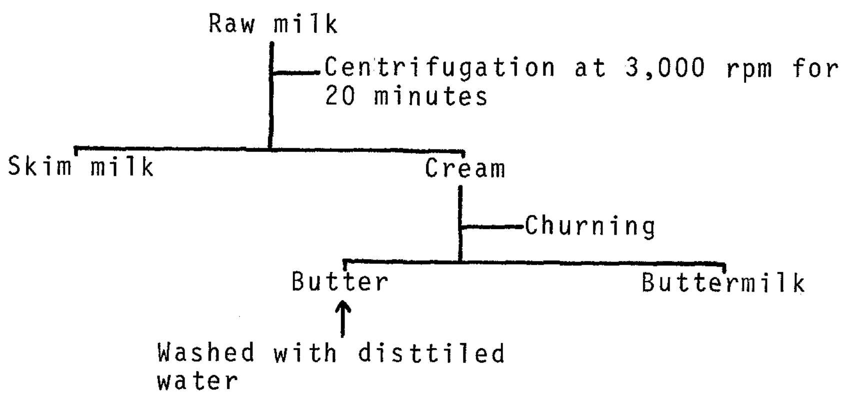

Fig. 1. The process of butter production.

Table 1. Volume of the butter and other dairy products

Metal	Group (ppm)	Raw milk (ml)	Skim milk (ml)	Cream (ml)	Butter (g)	Buttermilk (ml)
	1		895		34.4	47
Pb	10	1000	900	100	22.5	64
	50		898		33.5	51
	1		898		28.8	61
Cd	10	1000	886	100	29.3	63
	50		895		28.3	58

RESULTS

Lead and cadmium concentrations.

The concentrations of Pb and Cd in the butter and other dairy products and the pattern of increase or decrease of the Pb and Cd levels in the process of the dairy production are shown in Table 2 and Fig. 2, respectively. The Pb concentration of the skim milk was 2 - 6% higher than that in the raw milk. The Pb concentrations of the cream of the 1 ppm, 10 ppm and 50 ppm groups were decreased by nearly 25%, 39% and 45%, respectively, compared with the raw milk. The Pb concentration was markedly lower in the butter than in the cream. There was a 50 - 60% decrease in the 1 ppm group, an 80 - 88% decrease in the 10 ppm group and a 91 - 95% decrease in the 50 ppm group compared with the raw milk or with the cream (Fig. 2). On the other hand, the Pb concentration of the buttermilk was around 2.5 times more than that of the cream.

The Cd concentration was slightly higher in the cream than in the raw milk. In the 1 ppm, 10 ppm and 50 ppm groups, the Cd concentrations of the cream were decreased by approximately 35%, 55% and 49%, respectively, compared with the raw milk (Fig. 2). There was a 94 - 98% decrease of the butter Cd concentration compared with raw milk or with the cream. In both the butter and buttermilk, there were significantly lower Cd than Pb concentrations.

Table 2. Lead and cadmium concentrations of the butter and other dairy products[1]

Metal	Group (ppm)	Skim milk	Cream	Butter	Buttermilk
Pb	1	1.03 ± 0.02 (+3.0)	0.75 ± 0.09 (-25.0)	0.36 ± 0.04 (-52.0)	1.57 ± 0.11 (+196.2)
	10	10.20 ± 0.26 (+2.0)	6.04 ± 0.70 (-39.6)	1.17 ± 0.03 (-80.6)	11.26 ± 0.25 (+158.2)
	50	52.80 ± 1.65 (+5.6)	27.32 ± 0.48 (-45.3)	2.23 ± 0.36 (-91.8)	51.07 ± 1.34 (+157.9)
Cd	1	1.02 ± 0.02 (+2.0)	0.65 ± 0.04 (-35.0)	0.02 ± 0.01** (-97.5)	0.71 ± 0.05** (-61.3)
	10	10.38 ± 0.10 (+3.8)	4.51 ± 0.25 (-54.9)	0.15 ± 0.02** (-96.7)	5.87 ± 0.11** (+111.9)
	50	51.60 ± 1.23 (+3.2)	25.54 ± 1.17 (-48.9)	1.42 ± 0.05* (-94.4)	30.93 ± 0.63** (+115.9)

1= Mean ± s.d. μg/g wet weight.
*$p < 0.02$, **$p < 0.001$ with respect to the Pb groups.
The percent decrease or increase vs. the previous process is shown in parentheses.

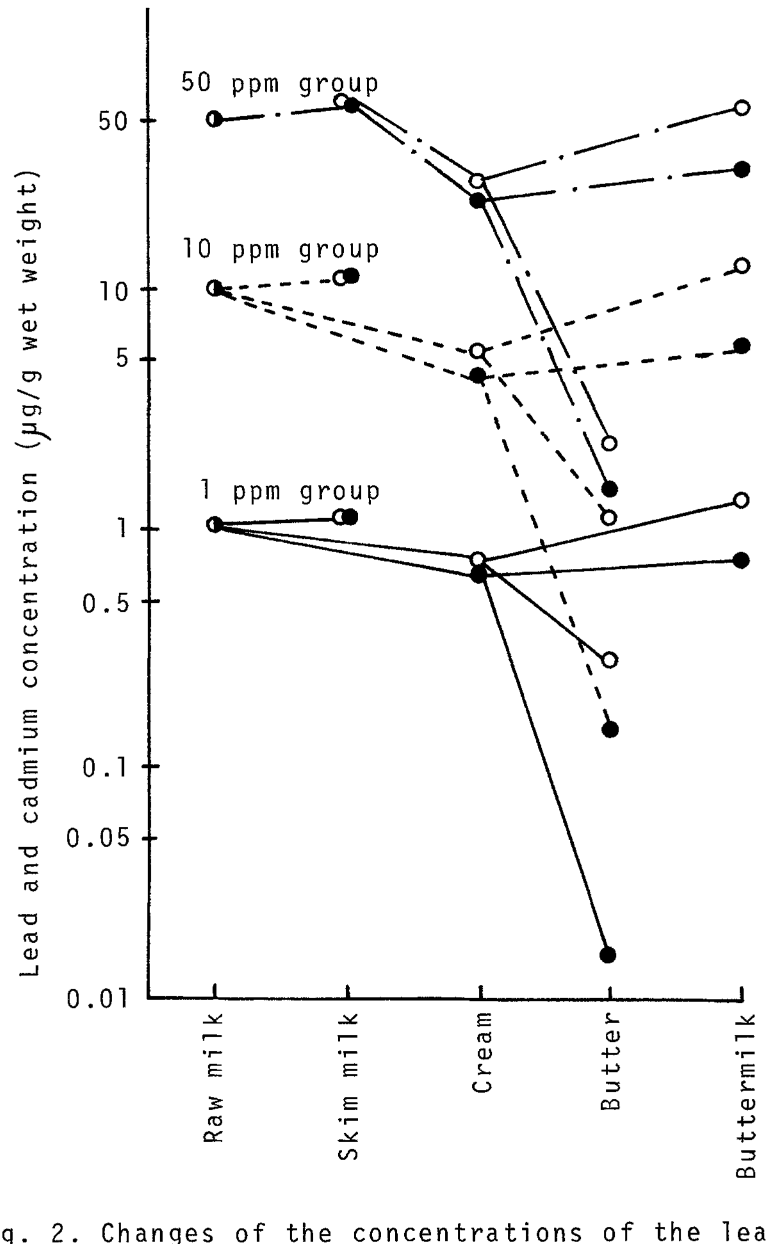

Fig. 2. Changes of the concentrations of the lead (open circle) and cdamium (filled circle) in the process of the butter production.

Lead and cadmium contents

The Pb and Cd contents in the butter and other dairy products are shown in Table 3. The transfer rate of the heavy metals from the raw milk to the skim milk was 90 - 99%. The transfer rate from the cream to the butter was 2.7 - 16.3% in the Pb groups and 0.7 - 1.5% in the Cd groups. The transfer rate was significantly higher in the Pb groups than in the Cd groups. Of the Pb contents, some 0.15 - 1.2% and, of the Cd contents, 0.04 - 0.08% were transferred from the raw milk to the butter. A part of the Pb and Cd in the butter was fluxed by washing in the water, except in the 1 ppm Pb group.

Table 3. Lead and cadmium contents of the butter and other dairy products (mean ± s.d.)

Metal	Group (ppm)	Skim milk (mg)	Cream (μg)	Butter (μg)	Buttermilk (μg)
Pb	1	0.92 ± 0.02 (92.2)	75.3 ± 9.8 (7.5)	12.3 ± 1.5 (1.2)	63.7 ± 5.4 (6.3)
	10	9.19 ± 0.26 (91.9)	604.6 ± 70.8 (6.0)	26.4 ± 1.7 (0.2)	547.0 ± 12.5 (5.4)
	50	47.40 ± 1.17	2,730 ± 50	74.8 ± 12.1	2,600 ± 70
Cd	1	0.91 ± 0.02 (91.2)	65.3 ± 4.5 (6.5)	0.5 ± 0.1 (0.04)	33.5 ± 0.2 (3.3)
	10	9.19 ± 0.24 (91.9)	451.6 ± 25.7 (4.5)	4.3 ± 0.4 (0.04)	367.2 ± 7.3 (3.6)
	50	46.20 ± 1.10 (92.4)	2,540 ± 120 (5.1)	40.3 ± 1.4 (0.08)	1,790 ± 30 (3.5)

The percent content vs. raw milk is shown in parentheses.

DISCUSSION

This study is concerned with the transfer of Pb and Cd into butter and other dairy products produced in the process of butter-making. As shwon in Fig. 1, the first stage in butter-making involves putting milk into a centrifugal separator and separating skim milk from cream. At this stage, 90% or more of the Pb and Cd in the milk is transferred into the skim milk, resulting in higher concentrations of these heavy metals than in the original milk. This may be quite natural considering that the yield rate of skim milk accounts for 90% of the original content and that its water content is approximately 92%. Skim milk is then concentrated in a vaccum to be sold as condensed milk or spray dried to be sold as powdered milk. Therefore, if the original milk is contaminated with these heavy metals, even if the degree of this contamination is relatively low, it does pose a danger. The Pb and Cd contents in the cream, on the other hand, were as low as 5 - 7%. Even then, as it will be sold as fresh cream as it is or frosen to be sold as ice cream, it is necessary to pay sufficient attention to not contaminating the original milk.

During the second phase of butter-making, cream is separated by churning into butter and buttermilk. The Pb and Cd contents in the butter showed a marked decrease, in particular, the Cd contents, which were 0.04 to 0.08% as compared with Pb contents of 0.1 to 1.2% (a compared with the raw milk). The difference in the Pb and Cd contents in the butter may be related to the components of butter. Pb accumulates readily in fat [KITAMURA 1974], and 100 g of butter contain 81.0 g of fat. Cd, on the other hand, is known to bind easily with metallothionein, which is a protein with a molecular weight of 6,000 - 10,000 [IMURA et al. 1980]. Eighty-five percent of the proteins in milk is casein, which has a molecular weight of 20,000 - 100,000, and, in addition, 100 g of butter contain only 0.9 g of protein. The proportion of Pb contents in the butter tended to be higher with the 1 ppm group than with the other groups. The authors supposed that this was because, as the Pb level in the original milk increases, the accumulation in the fat comes nearer to the saturation point.

The Pb and Cd levels in buttermilk are high, but, since buttermilk is discarded, there is no problem involved. The discrepancy between the total volumes of Pb and Cd in the butter and buttermilk and those in the cream, which was found in all groups except for the 1 ppm Pb group, was believed to be attributable to partial loss of the heavy metals in the process of washing the butter.

Because of the way butter was made in this study, which did not include the comprehensive operation of the factory procedure as the final process, the water content of the butter produced was approximately five times higher than that of commercially marketed butter, which is 15%. Considering that Pb and Cd were found to be fluxed when the butter was washed with water, it would appear that, if the butter obtained in this study were compressed, the levels of these heavy metals would decline still further. As such a tendency is particularly strong with Cd, even when the original butter is contaminated with 50 ppm of Cd, the level of Cd in the compressed butter would probably not exceed

0.28 ppm. In reality, however, contaminated milk is not used as a raw material for making dairy products, and the Pb and Cd concentrations in milk are ordinarily 0.012 - 0.154 and 0.002 - 0.0037 ppm, respectively [HOSOGAI et al. 1978, MITCHELL 1981]. Therefore, it was suggested that the possibility that butter is contaminated with either of these heavy metals is extremely small.

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Accepted October 17, 1982