Iodine content in milk from German cows and in human milk: new monitoring study

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Abstract. Objectives: Milk can provide more than 1/3 of the iodine content in human diet. Moreover, iodine supply in cow’s milk in Germany has improved throughout the last decade. Since 1982, analyses of iodine content of cow’s and human milk have been undertaken regularly in the State of Thuringia (East Germany). Data show increasing iodine concentration in milk over the past few years. Nonetheless, dietary supply of iodine via milk needs to be continuously monitored. Material and methods: To investigate the latest trend of iodine content in milk over time, 135 samples of cow’s milk and 65 samples of human milk were analyzed by ICP-MS after digestion with tetramethyl-ammonium hydroxide. Samples of cow’s milk (conventionally and organically produced) were purchased from the same supermarkets in Thuringia in March and November every year between 2007 and 2011. Human milk samples were obtained on a voluntary basis from breast-feeding women in Thuringia during the same time period. Results: Samples of cow’s milk from 2007 to 2011 showed a mean iodine concentration of 122.0 ± 36.8 µg/l. There was no significant change during these 5 years (p > 0.05). In the same period, iodine content of conventionally produced milk was on average 51 µg/l higher compared to organically produced milk (p < 0.001). For all human milk samples, the mean iodine content was 170 ± 96 µg/l, with a range of 45.6 – 478.4 µg/l. In breast milk, not only were high variations present between samples of milk from the individual women, but iodine content also varied over lactation time. Conclusions: The current results demonstrate that in East Germany the average iodine content in cow’s milk has remained stable at an appropriate level during the last 5 years. Although iodine concentrations in human milk likewise reveal relatively constant values on average, individual variations can be substantial.

Introduction

According to a report published by the WHO in 2008, an estimated 266 million children worldwide have an insufficient iodine intake [1]. Moreover, 52% of these children live in Europe. Following reunification, an educational public awareness campaign to promote the use of iodized salt in households, canteens and food manufacturers was started in Germany. New data revealed that during the 1990s, endorsed by this voluntary iodine prophylaxis, iodine deficiency in the German population improved from low to almost adequate levels. Data supporting this process was reported in the German Health Interview and Examination Survey for Children and Adolescents (KIGGs, 2007) [2]. In this study, the median urinary iodine content of 17,641 children and young people equaled 117 µg/l. According to the WHO criteria, urinary iodine concentration of 100 – 200 µg/l is indicative of a sufficient iodine supply both for school children and adults. Further, an endemic iodine deficiency is not present if < 50% of the population manifest ioduria below 100 µg/l and if < 20% of the population has an ioduria below 50 µg/l. The KIGGs study reported 40% of the German population as having iodine content below 100 µg/l. The KIGGs study reported 40% of the German population having iodine content below 50 µg/l and 17% below 50 µg/l. Thus, Germany only marginally fulfilled the WHO criteria. Despite an average increase in excreted iodine content according to the KIGGs results, a good fraction still shows a moderate or even a severe iodine deficiency.

Results of the second largest German National Nutrition Survey published in 2008 showed not only an improved iodine supply in the German population, but according to
this study, the main sources for iodine constituted milk and milk products, followed by meat, meat products, and bread [3].

Dairy products, in general, are an important source of iodine delivering up to 40% of the total iodine intake in the German population [4]. Other countries also report similar results [5, 6, 7]. But, iodine content in dairy products is subject to variation by a variety of factors, like leaching the soil with iodine (soil – feed – milk path), and supplementing cattle feed with iodized mineral mixtures, which mainly leads to higher iodine levels in the milk [8, 9, 10]. However, new data suggests that milk iodine response curves should not be extrapolated linearly for iodine intakes, because secretion ratio decreased at high levels of iodine supplementation [8].

Milk iodine concentrations are, furthermore, subjected to seasonal differences. Higher iodine levels have been detected in winter than in summer milk [5, 6, 9, 11] due to a greater consumption of iodine-enriched mineral mixtures by cows during the winter months. In addition, Falkenberg et al. [12] found a negative correlation between iodine content of cow’s milk and milk yield.

Another important factor is the presence of goitrogenic substances in the fodder of milk-producing animals, illustrated, in particular, in the use of rapeseed cake in cattle feed. The rapeseed goitrogens, glucosinolates, reduce the iodine content of cow’s milk and milk yield [11].

In contrast, the use of iodophors as udder disinfectants as well as the deployment of cleaning agents in milking stations, production facilities, and milk tanks can increase the iodine content in milk [9]. On the other hand, heating processes such as pasteurization lead to a reduction of iodine concentrations in milk [8].

A few studies have indeed shown an increase of the milk iodine content during the last decade in Germany due mainly to an effective supplementation of iodine-rich mineral mixtures in dairy cattle fodder [13]. A similar increase has also been demonstrated for human milk, as a result of ingesting either iodine tablets and/or iodine-enriched nutritional supplements including iodized food [14]. Human milk is the sole iodine source for breast-fed new-borns and as such the sole determinant of the baby’s iodine supply. An adequate iodine intake in the first months of life is vital for development of the brain since iodine deficiency is associated with psychomotoric defects, congenital aberrations and cretinism [14]. For lactating mothers, the German Society of Nutrition (DGE) recommends an iodine intake of 260 µg per day to ensure a sufficient iodine supply for the suckling baby. Hence, iodine concentrations in breast milk of 150 – 180 µg/l are considered as adequate [15]. Furthermore, the WHO recommends a median urinary iodine concentration of 150 – 249 µg/l for lactating mothers as an indication of a satisfactory iodine supply [16].

Against this background, it was the aim of the present study to monitor possible variations of the iodine content in cow’s milk and human milk in East Germany during the last 5 years.

**Material and methods**

**Milk samples**

Every spring (March) and autumn (November) between 2007 and 2011, a total of 135 samples of cow’s milk was purchased from the same supermarkets and grocery stores in Thuringia (East Germany). Products in the stores had been delivered from the following dairies: Milchunion Hocheifel e.G., Weihenstephan, Sachsenmilch AG Leppersdorf, Osterland Milchwerke Thüringen GmbH, Alnatura Produktions- und Handels GmbH, HERZGUT Landmolkerei Schwarza e.G., Kaufland Privatkombinat and EDEKA Bio Wertkost. Milk samples differed in type of production and in fat content (Table 1). In addition, during the same period and in the same region, 65 samples of human milk were collected from breast-feeding women on a voluntary basis.

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<table>
<thead>
<tr>
<th>Year</th>
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<td>26</td>
<td>-</td>
<td>16</td>
<td>10</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>
Iodine content in milk

Analysis

Milk samples were freeze-dried at –20 °C. In the next step, 5 ml ultrapure water and 1 ml tetra-methyl-ammonium hydroxide (TMAH) were added to 0.5 g of the freeze-dried material for extraction at 90 °C for 3 h. After cooling to room temperature, ultrapure water was added up to a volume of 20 ml. The suspension was centrifuged by 4,000 rot/min. For analytical measurements, all digestion solutions were equally prepared by diluting (v/v) with ultrapure water at a ratio of 1 : 10 and by adding 40 µg tellurium/l as an internal standard [17]. Using the addition calibration procedure, matrix differences between the calibration and sample solutions were compensated for. Iodine stock solution (1 g iodine/l) was prepared from potassium iodide (Suprapure® 99.5%, Merck, Darmstadt). Standard solutions of 0, 5, 10 and 20 µg iodine/l were prepared daily from the stock solution to establish the calibration curve. Afterwards 40 µg tellurium/l was added to each standard solution. Iodine content of all samples was determined via inductively coupled plasma-mass spectrometry (ICP-MS) using ELAN DRC-e (Perkin Elmer, Waltham, MA, USA) (Table 2).

Analytic quality control

For analytical quality control, two reference materials were used: non-fat milk powder (NIST 1549) with an iodine content of 3,380 µg/kg (range 3,050 – 3,750 µg/kg) and milk powder BCR 150 with an iodine content of 1,290 µg/kg (range 1,110 – 1,470 µg/kg). The mean iodine content determined for the reference materials constituted 3,384 µg/kg for non-fat milk powder and 1,219 µg/kg for milk powder. Thus, values obtained for the certified reference materials corroborate with the certified concentrations at the 95% confidence limit. All samples were determined as duplicates. Blank values were analyzed before, between, and after every batch of samples.

Statistics

Statistical analyses were conducted using PASW Statistics version 18.0 (SPSS Inc., Chicago, IL, USA). All data was checked for variance homogeneity applying the Levene’s test. In case of variance homogeneity, differences between the groups were tested with the paired Student’s t-test. In case of variance heterogeneity, data was log 10+1 transformed. In addition, in case of variance heterogeneity, data was tested using the non-parametric Wilcoxon signed-rank test. The overall effect of time was assessed using one-way ANOVA (analysis of variance) followed by the Scheffe post-hoc test. For each comparison, p < 0.05 was considered as statistically significant. Results are expressed as mean values ± SD.

Results

No significant differences in iodine levels were detected between spring and autumn milk samples (Figure 1) and also between full-fat and skimmed milk (p > 0.05; data not shown). Organic milk samples had significantly lower iodine content in comparison to conventional milk (Figure 1).
Only slight differences in the iodine content in cow’s milk were apparent in the period between 2007 and 2011; differences were not significant (p > 0.05) (Table 3).

Similarly, there is no significant time-dependent variation of iodine content of the analyzed human milk samples during the years 2001 – 2011 (Figure 2).

From one lactating woman, we obtained nine milk samples (A) including three samples of colostrum. From each of the two other women, we collected 12 (B, C) milk samples during mid-lactation over a period of 3 months (Figure 3). Extremely high variations of iodine content were measured between the lactation weeks, particularly for cases A and C, however, no increasing or decreasing trend of iodine concentration could be detected.

### Discussion

In the current study, data on the iodine content of cow’s milk were obtained between 2007 and 2011. However, iodine concentrations of milk samples in Thuringia have been available for many years prior to 2007 (Figure 4). For instance, comparison of the actual data with that obtained in 1985 shows a significant increase of the iodine content in cow’s milk over time. In the former German Democratic Republic (East Germany), a prophylaxis program was initiated in 1983. This was not based on the principle of voluntariness such as in the Federal Republic of Germany (West Germany). Moreover, since 1986, iodine-enriched mineral mixtures had been fed domestic animals in East Germany (11 mg iodine per kg dry matter of ration) explaining the five-fold increase in levels of iodine in the cow’s milk during a period of about 10 years.

The first nationwide iodine monitoring in Germany was implemented in 1996. Results demonstrated a rise in urinary iodine excretion in the German population due to a widespread use of iodized salt in households, bakeries and meat products [19]. In addition, iodine content of milk and milk products had also increased [13, 14].

In contrast to former studies, no significant changes of the iodine content were found during the period from 2007 up to 2011 (Table 3). A similar study conducted by Johner et al. (2011) in West Germany, in the region of Dortmund, detected a small, but significant, iodine rise of 13 µg/l between 2004/2005 and 2009/2010 [18]. Similarly increased trends during the last 2 – 3 decades were also determined in other European countries. In Swedish cow’s milk, the iodine content increased by 75% between 1975 and 1995 – 1997 [20]. In the UK, iodine concentrations in milk samples had risen from 150 µg/l in 1991/1992 to 303 µg/l in 1995 [21].

The main reason for this increase in the iodine content lies in the more generous use
Iodine content in milk of iodine-enriched mineral mixtures in dairy cattle fodder. Since 2005, new legislation allows iodine supplementation at a maximum of 5 mg/kg feed dry matter [22]. This value exceeds the National Research Council recommendation for lactating cows (0.5 mg/kg dry matter), whereby up to 40% of excessive iodine is transferred highly efficiently into milk [23]. A study in Germany examining the iodine supply of beef cattle between 1996 and 2003 observed a considerable improvement [24]. It is assumed that this development still continues. Several studies have proven a significant dose-response relationship between the iodine content in cow’s fodder and the iodine concentration of dairy milk. Schöne et al. [10] found that over a feeding period of 14 days, iodine content of milk reflected the iodine dosages in feed highly significantly. Data is available showing that on adding an upper iodine concentration of 5 mg/kg to the feed, milk iodine content rises above 1,000 µg/l. Thus, it was recommended that such data should signal for a more responsible legislation that places an appropriate limit on the maximal iodine content in feed.

The relationship between iodine intake in lactating Holstein cows and iodine concentrations in their milk was analyzed by Norouzzian [8]. The author reported that basal diet supplemented with either ~ 0.5 mg iodine per kg or with potassium iodide at 2.5, 5, or 7.5 mg/kg feed over a 7-week period increased iodine concentration of milk with each increase in dietary iodine from the basal value of 162 ng/ml to 534, 560 and 608 ng/ml, respectively. Further, the author postulated that milk iodine response curves for iodine intakes should not be extrapolated linearly, due to a reduced secretion ratio at higher levels of iodine supply.

Regarding iodine concentrations in organic milk, we observed significantly lower concentrations each year compared with conventionally produced milk (Figure 5). Similar results were detected by several other authors [18, 25]. Various factors may be responsible for the lower iodine content in organic milk than in conventional milk, for example, a reduced use of iodine-containing mineral mixtures and fewer teat dips in organic farms. In the survey of Hejtmankova et al. [11], cow’s milk from several farms in Central and Northern Bohemia was analyzed over a period of 17 months. The authors found that iodine content in milk was significantly reduced when the cows were fed a rapeseed-enriched diet in comparison with cows on a diet without rapeseed cake. They also postulated that fresh fodder supposedly contains more goitrogenic substances. Indeed, this opinion is supported by experimental findings showing that the season of milk sample collection has no statistically significant influence on milk iodine levels when dairy cows are fed a diet supplemented with rapeseed cake throughout the year [11].
Other authors describe considerable differences of iodine content between summer and winter milk. Preiß et al. [26] found the highest iodine content in March and April; lowest levels were detected in November and December. In winter, fodder is enriched with iodine, whereas during the summer season, cows get partially fresh fodder. As already shown, it is assumed that fresh fodder contains more goitrogenic substances. However, in our analyses, we could not detect a similar relationship.

In our study, an actual mean iodine content of 122 µg/l (2007 – 2011) could be verified (Table 3). This result is somewhat higher than the data of Johner et al. (2011) who found an iodine content of 98 µg/l (2004 – 2010) in the Northrhine-Westfalia region, using Sandell Kolthoff reaction. However, analytical method comparisons have demonstrated a good agreement of both methods [18].

Since no milk samples had excessive iodine concentration (Figure 6), it can be excluded that milk consumers have too much iodine intake via ingestion of normal quantities of milk and milk products. The committee “Residue Problems through Medicinal Products” of German Veterinary Medical Society recommends a total iodine content of milk of not more than 500 µg/kg. All cow’s milk samples collected during the study period fulfill this criterion.

**Human milk**

Pregnant and lactating mothers as well as their fetuses and infants constitute the groups with the highest risk for iodine deficiency due to their elevated iodine requirement. Unfortunately, current nationwide data regarding iodine status of mothers and mothers-to-be is not available. In the German State of Bavaria, a median urinary iodine concentration (UIC) of 153 µg/l was detected in pregnant women [27]. This value meets the WHO targets of UIC for this group (150 – 249 µg/l) and signifies a better iodine supply of the mothers during the last decades. These results were confirmed by the increased breast milk iodine concentration in our study (Figure 2). The mean iodine concentration of human milk samples in our survey is twice as high as those observed in 1994 and more than 12 times higher than values from 1982 [14]. However, since 2001, no significant changes in iodine concentration in human milk have
Conclusion

On average, between 2007 and 2011 cow’s milk contained 122.0 ± 36.8 µg/l iodine. Consumption of 0.5 l/day of this milk delivers about 60 µg iodine corresponding to about one third of the daily recommendation. The highest iodine concentration found in cow’s milk amounted to 207 µg/l. The iodine concentration of conventionally produced milk exceeded that of organically produced milk significantly. Based on this data, an excessive intake of iodine by milk and milk products can be excluded.

In breastfeeding mothers, extreme short-term variations in the iodine content of milk between < 50 and > 400 µg/l were observed. In all, during the last decade, the mean iodine content of human milk remained at a constant level.

References

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