Journal of Elementology ISSN 1644-2296

Sager M. 2018.
Content of elements and trace elements in Austrian commercial dairy products.
J. Elem., 23(1): 381-400. DOI: 10.5601/jelem.2017.22.1.1421

ORIGINAL PAPER

CONTENT OF ELEMENTS AND TRACE ELEMENTS IN AUSTRIAN COMMERCIAL DAIRY PRODUCTS

Manfred Sager

Competence Center for Elements
Austrian Agency for Health and Food Safety, Austria

Abstract

Screening of the elemental composition of various, commercially available dairy products should provide a tool for consumers and dietary advisers for making a proper selection, with respect to the animal of origin and fat content, respective a shift to soy products. Using a combination of ICP-OES and ICP-MS multi-element techniques, up to 35 total elements were determined in milk and dairy products after enrichment by freeze drying. Influences of the fat content and additives were outlined for cow-derived products, and respective tables given in dry matter as well in wet weight. Some differences between products from cows, goats and sheep were found, which appeared small, however, relative to the composition of soymilk, which resembles a plant sample. Principal component analysis of the entire dataset (excluding cream, sour cream and additive containing products) clearly resulted in 3 components, which contained the geochemical relations Ca-Sr, Ca-Ba, and Na-I in different components. With respect to Recommended Daily Intakes, one liter of milk of any kind satisfies the needs of Ca, Mg, P, and I, as well as half of K and Zn. Levels of many other elements, in particular those of low physiological interaction (e.g. Ti, rare earths, B, Be), were below or close to detection limits. During separation of cream and whey, ions largely prefer to stay in the whey. Addition of 1% cocoa increases the content of Cu, Fe and Mn. Cream and creme fraiche differ just marginally. Some differences of Austrian milk and milk powders and infant formulas sampled in Tanzania are outlined.

Keywords: milk, cream, goat milk, sheep yoghurt, soy-drink, iodine, rare earths, essential elements, nutrient elements, nickel.

Manfred Sager, PhD MSc, Competence Center for Elements, Austrian Agency for Health and Food Safety, Spargelfeldstrasse 191, A-1220 Vienna, Austria; e-mail: herz18@tele2.at

INTRODUCTION

Milk is the basic food for all small mammals. Since prehistoric times, milk and dairy products have been nutritionally important and valuable food items of animal origin, particularly for children. Enlarged availability of meat in Europe and North America, however, has decreased their importance for human nutrition within recent decades, and milk consumption is gradually declining. Within the last 60 years in Austria, annual meat consumption per person has doubled, whereas milk consumption has been lowered to about half instead (AMA 2016). In Austria, milk production in 2016 is estimated to be about 3.2 million tons, and therefore is still of economic importance (AMA 2016). In order to promote the consumption of milk and dairy products, a profound database about their composition is needed.

Modern trade offers a large selection of dairy products to the consumer, including various fat content levels, additives, and even originating from different animals. If no specific animal is labelled, the origin of milk and dairy products (at least within the EU) is from a cow, but products from sheep and goats are also sold. Soy-based beverages (soymilk) have been promoted as milk substitutes of plant origin for vegan consumers. Although they look like milk and might be used like milk, their taste is quite different. Consumers are ready to pay higher prices for special products, but they are hardly aware whether there are any differences in trace element composition. Therefore, detailed composition and consequences for trace element supply in human nutrition should be outlined in detail.

Usual quality control of milk and dairy products relies on fat and protein content as well as hygienic parameters. But milk is also a source of nutritionally important trace elements. The total content of very few elements correlates with fat, like K (negative), or with protein, like K and S – positive (Sager, Hobegger 2013), thus rendering it impossible to extrapolate the fat and protein content to trace element levels.

Total element data reported in references often pertain to single farms or small regions, but hardly ever to commercially available products in big cities. Information about non-metals (B, Si, S, F, Cl, Br, I) and elements of lower or unknown physiological activity (Li, Rb, Cs, Ba, Ti and others) is rarely found. In particular for the latter, concentration values cover a wide range, maybe due to analytical uncertainties and a lack of respective certified reference material (reviewed in Sager, Cadar, Simedru 2016). Complete datasets of commercially available dairy products of the entire periodic system are rare, and therefore this work aims to give a compilation of data from as many elements as possible from the same samples.

Investigations of the content of elements versus molecular weight have shown that cationic trace elements in milk always occur bound to proteins or other ligands to achieve high digestive availabilities. To the contrary, addition of Fe- and Cu-salts to milk causes oxidation and worsens the flavour

(Knowles et al. 2006). Thus, it is not easy to predict the partition of inorganics between cream and whey during dairy processes of respective separations. Data of the entire element spectrum from cream to skim milk will help to conclude which elements have some affinity to the lipid phase and which strictly stay in the whey.

Investigations performed in our laboratory showed that trace element composition of cow milk is rather uniform (Sager, Hobegger 2013) and, after mixing milk from various sources, differences arising from cows‘ breeds and lactation time should be equalized. But during processing, separation between high-fat and low-fat components occur. Moreover, there is contact with steel vessels, fermentation products and additions. Thus, salt additions increase the content of P, K, Al, Li and rare earth elements in processed cheese, and vessels raise the Cu content in hard cheese (Sager 2012). Storing of raw milk in glass vessels yielded higher trends for Si, B, Li, Na, Rb, Cs and Ba, with respect to storing in plastic containers (Sager 2014), but ranges were overlapping.

In order to prove deviations in milk composition due to future feeding practices, it will be necessary to rely on a dataset based on a large number of most probably uncontaminated samples and created for comparison purposes.

The aims of this study are manifold. First of all, a comprehensive dataset of the content of many elements as possible is given. Because much is still unknown about interelement effects, it is surely meaningless to publish in recent papers data of individual elements, e.g. Pb and Cd, without any information about the other elements. New data from high and low physiological interactions offer the possibility to find new relations among them. The consumer can choose between various dairy products, which are largely discriminated by the fat and acid content. If somebody is forced to lower an intake of calories, how will it change the intakes of trace elements, phosphates and sulfur compounds? What about the substitution of dairy products by soy-derived products?

MATERIAL AND METHODS

According to the Codex Alimentarius Austriacus, commercially available dairy products have been standardized with respect to their fat and acid content, and the dataset in this work adheres to these categories. Further details (e.g. company, product name) are subject to data protection. Unless labelled otherwise, dairy products have been processed from cow milk. Unless labelled otherwise, yoghurts do not contain flavour additions.

A total of 130 samples was investigated, and the number of samples of each item is given in the result tables. Most of the samples were obtained as subsamples of 20-30 ml collected during official food control visits in shops all over Austria, from January till October 2014, and stored deep-frozen in 50 ml plastic vials. All dairies used in-lined bloc-packs or cylindrical plastic beakers as it is current common practice, thus no sample was supplied in glass. There were no reasons for complaints due to routine parameters. After the first evaluation, additional sheep, goat and soy products were bought in nearby supermarkets.

The samples were weighed and freeze-dried (device: Christ Alpha 1-4) without changing the vessel, homogenized by means of a plastic spatula, and an amount 1.00 g (0.70 g in the case of full cream and Creme fraiche) was digested in pressure vessels with 8 ml of a special K-chlorate-nitric-acid [20 g $KClO_3$ (Merck p.a. Art 4944) + 200 ml H_2O+80 ml HNO_3 (Nitric acid, 65% suprapure, Merck 1.00441.1000)] solution, microwave heated and finally made up to 25 ml in plastic volumetric flasks (2-3 replicates; Sager 2011*a*). For later batches, in order to obtain K and Rb (because the digestion solution contains more of them than the samples do), and for control reasons, 0.25 g of sample were digested with 3.8 ml HNO_3, and made up to 25 ml too.

As a device, an MLS 1200 mega high performance microwave digestion unit (MLS GmbH, D-88299 Leutkirch) was used, programmed at 3 min 250 W/2 min 0/5 min 250 W/5 min 400 W/5 min 500 W. Because boron and silicon were also determined, contact with glass had to be strictly avoided. For ICP-OES multi-element determinations, a Perkin-Elmer Optima 3000 XL (Perkin Elmer, Norwalk, Connecticut) instrument with an axial torch was used. Several metal cations could be determined from both digestates, and just K and Rb could be deterimed from HNO_3-digestate only, while the non-metals B, S and Si – from the $KClO_3$-HNO_3-digestate only. For the ICP-OES, calibrant solutions for running the undiluted and 1+1 diluted digests were matrix matched with $KClO_3$-digestion solution. For the main elements Na-Ca-Mg-P-Sr, dilutions had to be prepared, as well as separate sets of calibrants to run for the non-metals B-Si, as well as for Ce-La-Sc-Ti-Y.

ICP-MS measurements for Bi, Cd, Co, Mo, Ni, Pb, Tl, as well as Y and the Rare Earth Elements were performed with an Perkin Elmer Sciex ELAN DRC II at 1+9 dilution, after the addition of indium as internal standard.

Total iodine was determined as iodate under acid oxidizing conditions, by ICP-MS utilizing standard addition (Sager, Hobegger 2013). Oxidation to yield non-volatile iodate is obviously so quick that no losses occurred. Because organo-iodine compounds are also included, the results were sometimes slightly higher than obtained via alkaline extraction of iodide (Laguna-Paredes 2009). For 1+9 dilution, a detection limit of 0.004 mg kg^{-1} could be achieved, but because of their iodine high level, dairy products had to be diluted at 1+19 or 1+49. Finally, results from all replicates and dilutions were aggregated in a table and averaged to reach one figure per sample and element. The detection limits given in table 1 refer to ICP-OES from the 1 g/25 digests, others from the ICP-MS (elements written in italics). ICP-OES und ICP-MS well agreed for Cd, Co, Ce and La, as far as above the detection limit of the ICP

-OES. Just in case of Pb close to its detection limit, the ICP-OES yielded too high results.

The results were re-calculated to fresh weight by using the weight loss obtained from freeze-drying. Data in the final table were processed and separated according to the fat content respective the source animal. The table with the final results contains the medians as well as the concentration ranges without the smallest and largest 10% of individual values; this does not change the median and rapidly expels outliers (Sager, Mittendorfer 1997), because tests for outliers assuming the Gaussian distribution of data just skip a maximum of about 10% of data from each end.

Mean and standard addition should be given only if the distribution of data is Gaussian.

All data were processed as boxplots to visualize trends and overlaps. Boxplots show the median, the 25-75% range in the box, and the entire range.

Principal component analysis was done with an SPSS (version 20) statistical program.

RESULTS

Tables 1*a* and 1*b* show the concentrations found in dairy products obtained from cow milk, divided according to their fat content. Table 1*b* was recalculated from water content and dry weight data. Data below the detection limit should yield a Gaussian frequency distribution around zero, and for parameters which are obviously sometimes smaller than this, it is more reasonable to give concentration ranges. In particular, the ICP-OES was not able to detect Cd, Ce, Co, La, Mo and V. It can be seen that values of the content met in natural fat milk, whole milk, semi-fat milk, low-fat milk and also in pure yoghurts were largely overlapping within one standard deviation. Levels met in cream, however, were generally lower, except for Fe and Al.

From this, data from milk and pure yoghurts were compiled together (66 samples) to compare with similar data obtained for goat milk and yoghurts (8 samples), sheep yoghurts (13 samples) and soy drinks (5 samples; Tables 2*a* and 2*b*). In this case, sufficient ICP-MS data were available to obtain more information about low-level trace elements. In many cases (Al, Co, Cs, Cu, I, Li, Mg, Mn, Mo, Sr), levels in dry mass increased in milk from cow to goat to sheep. Cow milk was lowest in Fe, Rb, and S, whereas goat milk/yoghurt was lowest in Ca, Cr, Na, P, and Si. Sheep yoghurt contained more Ba and Sr. Pb and Cd, which have to be looked at during official quality control because of legal thresholds, as well as Rare Earth elements and others, were all at or close to detection limits.

Soy-based milk supplements clearly reflect green plant origin and contained significantly more Al, B, Cd, Cu, Fe, Mg, Mn, Mo, Si and above all Ni,

Table 1*a*

Concentrations in cow milk and its dairy products (mg kg^{-1} DM) by ICP-OES (ranges are given for many data below the detection limit; I from ICP-MS)

Specification	Cream (30-36% fat)	Cream + sour cream(10% fat)	Milk of nat. fat	Whole milk (3.5% fat)	Semi-fat milk (1.5% fat)	Low-fat milk (0.5% fat)	Yoghurts
(%) H_2O	58.8 ± 2.8	77.4 ± 1.5	84.5 ± 2.6	85.4 ±2.0	87.5 ±1.5	86.4 ±4.1	84.2 ±3.0
Al	0.64 ± 0.42	0.55 ± 0.21	0.76 ± 0.45	0.58 ± 0.39	0.35 ± 0.34	0.33 ± 0.41	0.76 ± 0.27
B	< 0.2	0.33 ± 0.14	0.92 ± 0.50	0.58 ± 0.23	-	-	0.97 ± 0.59
Ba	0.07 ± 0.04	0.18 ± 0.08	0.31 ± 0.17	0.42 ± 0.14	0.47 ± 0.08	0.52 ± 0.24	0.48 ± 0.20
Be	<0.002– 0.010	< 0.002-0.013	<0.002 - 0.006	< 0.002 – 0.005	<0.002 – 0.006	<0.002-0.006	< 0.002
Ca	2028 ± 300	4753 ± 585	11219 ± 2486	10392 ± 1695	12356 ± 1905	13218 ± 3101	11322 ± 2421
Cr	< 0.03	<0.02 – 0.04	0.11 ± 0.08	0.11 ± 0.05	0.16 ± 0.07	0.17 ± 0.06	0.14 ± 0.07
Cu	< 0.04 – 0.09	0.13 ± 0.07	0.32 ± 0.15	0.29 ± 0.09	0.31 ± 0.06	0.30 ± 0.08	0.34 ± 0.13
Fe	1.10 ± 0.43	1.31 ± 0.41	1.64 ± 0.37	1.41 ± 0.41	1.45 ± 0.19	1.35 ± 0.27	1.45 ± 0.30
I	0.59 ± 0.26	1.54 ± 0.84	2.70 ± 1.04	2.49 ± 0.68	3.40 ± 0.77	3.98 ± 0.78	1.96 ± 0.66
Li	< 0.005	0.013 ±0.003	-	0.018 ± 0.009	-	-	-
Mg	170 ± 22	400 ± 40	753 ± 110	785 ± 91	900 ± 106	918 ± 194	775 ± 205
Mn	< 0.01 – 0.08	0.11 ± 0.04	0.14 ± 0.03	0.16 ± 0.04	0.19 ± 0.03	0.18 ± 0.06	0.18 ± 0.07
Na	821 ± 112	2309 ± 725	4009 ± 771	3740 ± 547	4440 ± 713	4833 ± 879	4324 ± 800
Ni	< 0.02 - 0.10	< 0.02 - 0.07	< 0.02 – 0.05	< 0.02 – 0.26	< 0.02 – 0.09	< 0.02 – 0.09	< 0.02 – 0.10
P	1655 ± 188	3868 ± 616	7227 ± 1358	7221 ± 976	8525 ± 1117	9166 ± 1504	7064 ± 1647
S	555 ± 100	1312 ± 193	2293 ± 417	2360 ± 272	2911 ± 501	2920 ± 688	2447 ± 514
Si	1.6 ± 0.8	3.6 ± 0.6	8.0 ± 3.1	8.2 ± 3.7	-	-	12.8 ± 5.1
Sr	0.41 ± 0.09	1.18 ± 0.16	1.71 ± 0.72	1.97 ± 0.44	2.64 ± 0.33	2.95 ± 0.55	2.12 ± 0.81
Ti	< 0.03 - 0.05	0.03 ± 0.03	0.09 ± 0.04	0.05 ± 0.05	-	-	0.05 ± 0.01
Zn	6.7 ± 1.5	15.3 ± 1.4	29.7 ± 5.4	28.8 ± 4.8	34.8 ± 3.3	33.8 ± 9.5	29.6 ± 6.5

Data for Cd, Ce, Co, La, Sc, V: all below detection limit of ICP-OES

Table 1*b*

Concentrations in cow milk and its dairy products (mg kg^{-1} WW) by ICP-OES

Specification	Cream (30-36% fat)	Cream + sour cream(10% fat)	Milk of nat. fat	Whole milk (3.5% fat)	Semi-fat milk (1.5% fat)	Low-fat milk (0.5% fat)	Yoghurts
(%) H_2O	58.8 ± 2.8	77.4 ±1.5	84.5 ± 2.6	85.4 ± 2.0	87.5 ± 1.5	86.4 ± 4.1	84.2 ± 3.0
Al	< 0.1-0.44	<0.1–0.48	<0.1- 0.26	<0.1- 0.19	<0.1 – 0.18	< 0.1 – 0.13	< 0.1 – 0.15
B	< 0.10	0.07 ± 0.03	0.16 ± 0.07	0.11 ± 0.09	-	-	0.14 ± 0.03
Ba	0.033 ± 0.033	0.040 ± 0.017	0.068 ± 0.066	0.060 ± 0.020	0.073 ± 0.028	0.076 ± 0.029	0.085 ± 0.042
Be	0.0006-0.0041	<0.0005-0.0027	<0.0005-0.0011	<0.0005-0.0008	<0.0005-0.0007	<0.0005-0.0014	<0.0005
Ca	833 ± 113	1040 ± 144	1699 ± 294	1504 ± 228	1796 ± 705	1706 ± 162	1661 ± 408
Cr	< 0.01	< 0.01	0.015 ± 0.011	0.015 ± 0.009	0.023 ± 0.015	0.021 ± 0.005	0.022 ± 0.011
Cu	< 0.04	0.034 ± 0.021	0.062 ± 0.050	0.041 ± 0.014	0.053 ± 0.025	0.038 ± 0.003	0.046 ± 0.025
Fe	0.45 ± 0.15	0.28 ± 0.07	0.26 ± 0.09	0.21 ± 0.07	0.22 ± 0.12	0.18 ± 0.02	0.24 ± 0.06
I	0.21 ± 0.14	0.33 ± 0.17	0.42 ± 0.17	0.38 ± 0.14	0.49 ± 0.22	0.43 ± 0.12	0.37 ± 0.19
Li	0.0013 ± 0.0010	0.0027 ± 0.0007	-	0.0028 ± 0.0015	-	-	-
Mg	70 ± 7	87 ± 5	123 ± 31	113 ± 11	132 ± 54	119 ± 7	119 ± 24
Mn	0.011 ± 0.014	0.026 ± 0.010	0.024 ± 0.010	0.023 ± 0.010	0.027 ± 0.010	0.036 ± 0.033	0.030 ± 0.011
Na	338 ± 44	500 ± 140	607 ± 71	536 ± 73	641 ± 232	553 ± 67	667 ± 92
Ni	< 0.002-0.045	< 0.002- 0.015	<0.002-0.012	< 0.002-0.041	< 0.002-0.016	< 0.002-0.019	< 0.002-0.021
P	679 ± 54	831 ± 91	1102 ± 198	1035 ± 118	1242 ± 482	1120 ± 82	1094 ± 232
Pb	< 0.05	< 0.04	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
S	230 ± 33	285 ± 26	347 ± 45	343 ± 46	420 ± 152	377 ± 32	381 ± 87
Si	0.65 ± 0.34	0.77 ± 0.09	1.38 ± 0.36	1.32 ± 0.58	-	-	-
Sr	0.17 ± 0.08	0.26 ± 0.04	0.38 ± 0.37	0.28 ± 0.08	0.38 ± 0.13	0.34 ± 0.06	0.33 ± 0.12
Ti	0.017 ± 0.004	<0.001-0.014	0.015 ± 0.007	<0.001-0.021	0.024	0.012	0.009 ± 0.002
Zn	2.75 ± 0.45	3.40 ± 0.35	4.47 ± 1.02	4.15 ± 0.62	5.02 ± 1.89	4.34 ± 0.52	4.58 ± 0.89

Table 2*a*

Comparison of milk from cows, goats and sheep with soy drinks (mg kg^{-1} DM)

Specification	Cow	Goat	Sheep	5 Soy drinks
	mean ± SD	mean ± SD	mean ± SD	mean ± SD
(%) H_2O	85.6 ± 2.2	83.5 ± 4.9	80.8 ± 2.9	88.5 ± 3.9
Al	0.60 ± 0.41	0.89 ± 0.64	1.00 ± 0.44	22.3 ± 16.6
B	0.72 ± 0.32	0.64 ± 0.52	0.82 ± 0.49	8.6 ± 8.7
Ba	0.45 ± 0.17	0.43 ± 0.09	1.07 ± 0.33	1.92 ± 1.78
Be	0.0003 ± 0.0026	0.0017 ± 0.0031	-0.0004 ± 0.0017	-0.0005 ± 0.0029
Ca	11251 ± 2056	9339 ± 2601	11300 ± 2490	7448 ± 6090
Cd	0.0005 ± 0.0004	0.0006 ± 0.0007	0.0003 ± 0.0004	0.045 ± 0.007
Ce	0.008 ± 0.008	0.008 ± 0.015	-0.001 ± 0.003	0.029 ± 0.022
Co	0.003 ± 0.001	0.013 ± 0.010	0.016 ± 0.008	0.174 ± 0.058
Cr	0.128 ± 0.060	0.091 ± 0.091	0.139 ± 0.065	0.306 ± 0.125
Cs	0.0029 ± 0.0011	0.018 ± 0.014	0.060 ± 0.021	0.021 ± 0.020
Cu	0.303 ± 0.092	0.413 ± 0.200	0.592 ± 0.393	15.4 ± 5.5
Fe	1.46 ± 0.31	2.27 ± 0.42	2.08 ± 0.58	55.7 ± 35.2
I	2.74 ± 0.85	4.13 ± 1.07	6.53 ± 3.07	0.35 ± 0.41
K	10405 ± 1689	11805 ± 2497	5685 ± 1082	16790 ± 3006
La	0.003 ± 0.003	0.003 ± 0.009	-0.001 ± 0.002	0.019 ± 0.013
Li	0.020 ± 0.010	0.036 ± 0.015	0.042 ± 0.016	0.087 ± 0.041
Mg	816 ± 123	889 ± 241	944 ± 229	2303 ± 454
Mn	0.171 ± 0.050	0.383 ± 0.092	0.417 ± 0.144	29.1 ± 5.2
Mo	0.049 ± 0.009	0.098 ± 0.044	0.151 ± 0.076	2.79 ± 2.26
Na	4048 ± 671	2527 ± 958	3586 ± 1034	5245 ± 2314
Nd	0.003 ± 0.002	-0.001 ± 0.001	0.000 ± 0.001	0.017 ± 0.012
Ni	0.04 ± 0.06	0.05 ± 0.02	0.02 ± 0.04	5.94 ± 3.09
P	7529 ± 1196	7072 ± 1760	7411 ± 1721	7090 ± 3557
Pb	0.004 ± 0.008	-0.001 ± 0.007	0.000 ± 0.012	-0.001 ± 0.006
Pr	0.0006 ± 0.0007	0.0000 ± 0.0014	-0.0001 ± 0.0003	0.0041 ± 0.0029
Rb	1.77 ± 0.63	24.4 ± 19.7	19.1 ± 3.0	6.7 ± 3.8
S	2504 ± 406	2739 ± 475	2766 ± 405	3270 ± 805
Sc	0.001 ± 0.012	0.020 ± 0.013	0.019 ± 0.018	0.010 ± 0.017
Si	9.0 ± 4.2	6.6 ± 3.8	15.2 ± 6.7	141 ± 45
Sm	0.0004 ± 0.0003	0.0001 ± 0.0010	0.0000 ± 0.0002	0.0034 ± 0.0024
Sr	2.16 ± 0.61	2.57 ± 1.01	3.91 ± 1.40	8.24 ± 7.48
Ti	0.08 ± 0.05	0.10 ± 0.07	0.08 ± 0.04	0.49 ± 0.47
V	-0.01 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	0.09 ± 0.08
Y	0.0013 ± 0.0014	0.0003 ± 0.0015	0.0007 ± 0.0003	0.032 ± 0.029
Zn	30.5 ± 5.7	24.5 ± 7.2	25.6 ± 9.0	45.3 ± 14.6

Cow products include milk of 3.5%, 1.5%, 0.5% fat content (66 samples; 10 for ICP-MS). Goat products include milk and yoghurt (8 samples). Sheep products include only yoghurt (13 samples; 6 for ICPMS). Soy drinks (5 samples). ICP-MS data symbol given in italics.

Table 2*b*

Comparison of milk from cows, goats and sheep with soy drinks (mg kg^{-1} WW)

Specification	Cow		Goat		Sheep		Soy drinks	
	median	range	median	range	median	range	median	range
(%) H_2O	86.4	81.4 - 89.5	85.0	73.8 - 89.6	82	73.4 - 83.9	90.6	82.1 - 91.2
Al	< 0.1	< 0.1 - 0.26	< 0.1	< 0.1 - 0.43	0.17	0.10 - 0.47	1.66	0.71 - 8.11
B	0.084	0.053 - 0.222	0.105	< 0.03 - 0.205	0.131	0.051 - 0.314	1.069	0.130 - 2.497
Ba	0.058	0.031 - 0.117	0.076	0.033 - 0.134	0.195	0.100 - 0.284	0.165	0.068 - 0.472
Be	< 0.0005	< 0.0005- 0.0011	< 0.0005	< 0.0005- 0.0012	<0.0005		< 0.0005	
Ca	1546	1238 - 1873	1421	1047 - 1913	2152	1252 - 2550	943	188 - 1368
Cd	0.0001	< 0.0001- 0.0001	0.0001	< 0.0001- 0.0003	0.0001	< 0.0001- 0.0002	0.0042	0.0033 - 0.0074
Ce	0.0013	< 0.0002- 0.0029	< 0.0002	< 0.0002- 0.0069	<0.0002	< 0.0002- 0.0110	0.0023	0.0009 - 0.0118
Co	0.0006	0.0003 - 0.0007	0.0030	0.0002 - 0.0034	0.0039	0.0006 - 0.0048	0.018	0.008 - 0.041
Cr	0.019	< 0.005 - 0.028	0.016	0.005 - 0.025	0.023	< 0.005 - 0.047	0.025	0.024 - 0.049
Cs	0.0004	0.0003 - 0.0007	0.0039	0.0007 - 0.0158	0.0122	0.0008 - 0.0156	0.0014	0.0009 - 0.0051
Cu	0.040	0.025 - 0.081	0.057	0.043 - 0.106	0.078	0.032 - 0.214	1.57	1.33 - 2.08
Fe	0.187	0.148 - 0.374	0.410	0.199 - 0.470	0.386	0.263 - 0.620	4.93	0.361 - 17.9
I	0.407	0.211 - 0.642	0.662	0.384 - 0.979	1.168	0.204 - 1.953	0.021	0.002 - 0.192
K	1696	1418 - 1869	1641	1240 - 2367	1218	1000 - 1366	1766	1249 – 2372
La	0.0006	< 0.0002- 0.0014	< 0.0002	< 0.0002- 0.0035	<0.0002		0.0018	0.0004 - 0.0060
Li	0.0028	0.0010 - 0.0063	0.0055	0.0039- 0.0079	0.0085	0.0055 - 0.0229	0.0100	0.0019 - 0.0188
Mg	110	104 - 145	135	102 - 198	178	122 - 226	253	163 – 328
Mn	0.022	0.016 - 0.051	0.061	0.038 - 0.100	0.069	0.044 - 0.127	2.93	2.58 - 4.07
Mo	0.014	<0.005 - 0.042	0.016	0.004 - 0.042	0.029	0.012 - 0.052	0.391	0.053 - 0.543
Na	554	446 - 663	434	299 - 681	639	383 - 926	448	28 – 801

cont. Table 2*b*

Specification	Cow		Goat		Sheep		Soy drinks	
	median	range	median	range	median	range	median	range
Nd	0.0005	< 0.0002- 0.0008	< 0.0002	< 0.0002- 0.0030	<0.0002		0.0015	0.0004 - 0.0059
Ni	< 0.004	< 0.004 - 0.040	0.008	0.004 - 0.018	0.004	< 0.004 - 0.016	0.593	0.427 - 1.061
P	1040	936 - 1311	1116	805 - 1683	1397	924 – 1625	646	555 - 1148
Pb	< 0.002	< 0.002 - 0.004	< 0.002		< 0.002	< 0.002 - 0.006	< 0.002	< 0.002 - 0.006
Pr	0.0001	< 0.0001- 0.0002	< 0.0001	< 0.0001- 0.0008	<0.0001	< 0.0001- 0.0011	0.0004	0.0001 - 0.0015
Rb	0.27	0.17 - 0.47	4.03	0.94 - 8.57	3.90	0.36 - 4.49	0.61	0.48 - 1.23
S	339	311 - 438	394	321 - 494	515	416 – 600	388	252 - 437
Sc	< 0.004		< 0.004	< 0.004 - 0.006	< 0.004	< 0.004 – 0.007	< 0.004	< 0.004 - 0.006
Si	1.13	0.77 - 2.02	1.08	0.27 - 1.72	3.24	1.00 - 5.17	17.03	7.29 - 29.47
Sm	0.0001	< 0.0001- 0.0001	< 0.0001	< 0.0001- 0.0006	<0.0001	< 0.0001- 0.0008	0.0003	0.0001 - 0.0012
Sr	0.313	0.174 - 0.431	0.414	0.192 - 0.587	0.674	0.485 - 1.180	0.636	0.234 - 3.717
Ti	0.008	0.001 - 0.024	0.013	0.005 - 0.055	0.015	0.008 - 0.084	0.038	0.005 - 0.224
V	< 0.004		< 0.004		-0.001	-0.016 - 0.004	0.007	< 0.004 - 0.029
Y	0.0002	< 0.0001- 0.0003	< 0.0001	< 0.0001- 0.0006	0.0002	< 0.0001- 0.0011	0.0025	0.0005 - 0.0081
Zn	4.27	3.34 - 5.62	4.16	1.88 - 5.44	4.31	3.21 - 7.75	5.09	3.22 - 5.68

Cow products include milk of 3.5%, 1.5%, 0.5% fat content (66 samples; 10 for ICP-MS). Goat products include milk and yoghurt (8 samples). Sheep products include only yoghurt (13 samples; 6 for ICPMS). Soy drinks (5 samples). ICP-MS data symbol given in italics.

but less iodine and Ca. Some soy drinks contained Ca-salts labelled as additives (g l^{-1}), to approach the Ca levels met in cow milk; the addition was approximately 5 times the natural content. Table 2*c* shows the unrotated factor weights, obtained from Principal Component Analysis data, shown in Table 2*a*, which yielded 3 components representing 80% of cumulative initial Eigenvalues, within any combination tried. Surpringly, factor weights of Sr and Ba were not together with Ca, and Na not together with iodine within the same component. Factor plot 1 versus 2 in Figure 1 shows partition into different fields according to the origin, given on two scales.

Table 3 shows how additives might influence the concentration ranges found in dairy products. Whole-milk data are presented together with those

Table 2*c*

Factor weights of Principal Component Analysis (for data of Table 2*a* and Figure 1)

Specification	Component		
	1	2	3
(%) Variance	43.0	25.3	10.6
Ba	0.663	0.199	0.100
Ca	-0.168	0.931	-0.003
Cu	0.931	-0.061	-0.198
Fe	0.832	-0.196	0.240
I	-0.288	0.361	0.716
Mg	0.910	0.194	-0.059
Mn	0.954	-0.132	-0.139
Na	0.209	0.791	-0.239
P	0.034	0.864	-0.173
Sr	0.641	0.159	0.571

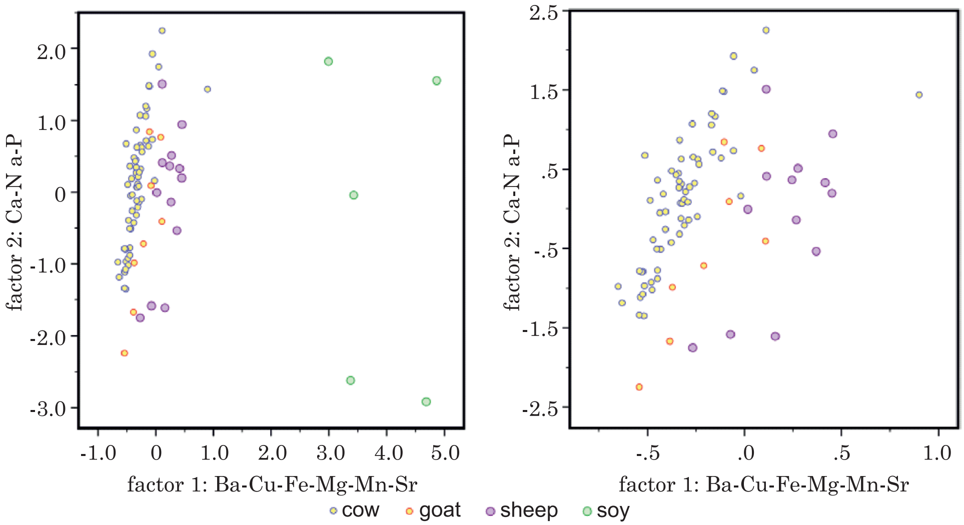

Fig. 1. Factor plots of Principal Component Analysis (different scalings)

Table 3

Whole milk and mixed products (mg kg^{-1} WW)

Specification	Whole milk		Cocoa milk		Acidophilus milk		Strawberry milk
	median	range	median	range	median	range	
(%) H_2O	85.9	82.7 - 87.6	81.5	79.5 - 84.5	86.7		77.4
Al	< 0.1	< 0.1 - 0.19	0.31	0.12 - 1.39	0.11	< 0.1 - 0.26	0.12
B	0.083	0.053 - 0.181	0.199	0.106 - 0.264	0.100	0.012 - 0.164	0.062
Ba	0.057	0.032 - 0.091	0.140	0.079 - 0.218	0.055	0.052 - 0.057	0.062
Be	<0.0005	<0.0005 - 0.0008	<0.0005	<0.0005 - 0.0006	<0.0005		<0.0005
Ca	1449	1226 - 1851	1204	1052 - 1490	1313	1206 - 1482	1180
Cd	<0.0002		< 0.002		< 0.002		< 0.0002
Ce	< 0.003		< 0.003		< 0.003		< 0.003
Co	0.0006	0.0003 - 0.0007	0.011	0.005 - 0.017	< 0.002	<0.002 - 0.003	0.0009
Cr	0.018	<0.005 - 0.025	0.019	<0.005 - 0.084	< 0.005	<0.005 - 0.011	0.005
Cs	0.0004	0.0003 - 0.0007					0.0005
Cu	0.038	0.025 - 0.064	0.377	0.145 - 0.533	0.029	0.020 - 0.032	0.025
Fe	0.188	0.121 - 0.345	1.572	0.362 - 6.98	0.160	0.145 - 0.211	0.310
I	0.390	0.225 - 0.589	0.170	0.044 - 0.629	0.407	0.387 - 0.429	0.049
K	1680	1418 - 1765					1532
La	0.0006	<0.0002 - 0.00135	<0.005		<0.005		<0.0002
Li	0.0021	0.0012 - 0.0051	0.0018	0.0015 - 0.0025	0.0043	0.0040 - 0.0055	0.0012
Mg	109	104 - 130	130	116 - 157	110	96 - 112	94
Mn	0.021	0.014 - 0.036	0.298	0.122 - 0.600	0.022	0.018 - 0.023	0.094

cont. Table 3

Specification	Whole milk		Cocoa milk		Acidophilus milk		Strawberry milk
	median	range	median	range	median	range	
Mo	0.008	0.007 - 0.009					0.008
Na	545	442 - 608	551	423 – 633	481	341 - 559	462
Nd	0.0006	<0.0002 - 0.00084					<0.0002
Ni	<0.004	<0.004 - 0.041	0.098	0.055 - 0.140	0.013	0.006 - 0.021	0.007
P	1009	919 - 1197	977	822 - 1149	1004	903 - 1097	901
Pb	<0.002	<0.002 - 0.004					0.005
Pr	0.00015	<0.00002 - 0.00023					<0.00002
Rb	0.250	0.167 - 0.470					0.135
S	330	312 - 418	328	298 – 384	354	343 - 364	319
Sc	< 0.004		< 0.004		< 0.004		< 0.004
Si	1.11	0.81 - 2.02	1.67	1.11 - 3.36	0.99	0.48 - 3.79	1.16
Sr	0.281	0.196 - 0.391	0.385	0.338 - 0.488	0.214	0.212- 0.262	0.337
Ti	0.007	<0.001 - 0.028	0.063	0.006 - 0.138	0.005	0.005 - 0.012	0.003
V	< 0.004		< 0.004	< 0.004 - 0.006	< 0.004		< 0.004
Y	<0.0002		< 0.002		< 0.0002		< 0.0002
Zn	4.04	3.37 - 5.28	3.82	3.18 - 5.10	2.83	2.70 - 4.52	3.72

of cocoa milk, acidophilus milk, and strawberry milk (2.35% strawberries labelled). Despite an addition of about just 1%, cocoa significantly rose levels of Al, B, Ba, Cu, Fe, Mn and Ni, because much more of these elements occurs in green plants than in food of animal origin (meat, eggs, milk), which had been analyzed in the same laboratory previously (Sager 2005, 2011*b*, 2013, Sager, Hobegger 2013). To the contrary, acidophilus and strawberry additions were of no visible effects on whole milk.

Among high-fat products, creme fraiche, which might contain additional salts and herbs, contained more Na and Li than full cream (Table 4).

Table 5 shows medians and concentration ranges found in commercially available Austrian milk (natural fat content + 3.5% fat), together with commercial full-cream milk powder and infant formulas sampled in Tanzania (but produced in Europe, New Zealand and elsewhere) in 2011 (Sager, McCulloch, Schoder 2017), which might be very important for the feeding of babies, who will not receive quite the same nutrition. Full cream milk powder contained more Rb, Cs, Fe and Mo than the milk sold in Austria (based on dry matter), but sometimes less sulfur. The infant formulas were lower in Ca, K, Mg, Na, P and S, but intentionally fortified with Cu and Fe, which has to be labelled as such. Other elements like I and Zn remained at the same levels throughout.

DISCUSSION

General

The discussion follows the aspects related to consumers, the processing of milk, ist origin, supervision, and the comparison with other published data. A comprehensive review of literature data, however, would be beyond the scope of this article. But one of the reasons for the author to start analyzing milk and dairy products in 2009 was the huge differences of published data in milk for Cr, Ti and Tl ranging about 2 orders of magnitude, and for Li, Rb, Cs, Sr, Ba, La, Co, and Mo of about order of magnitude at that time (Anderson 1992, Anke et al. 1993, Coni et al. 1995, Hódi et al. 2009).

Regional and seasonal variations in raw milk composition from presumably similar locations within Lower Austria have been already outlined (Sager, Hobegger 2013; Sager 2014). Pooling of raw milk in a dairy prior to processing does not permit us to ascribe individual variations to feeding respective annual cycling of feed plants, lactation day and cow breed. The traded products probably largely equalize these effects.

Dairy products and human nutrition

Fortunately, all samples which had been delivered as subsamples from official food control met the requirement for consumption, and no unexpected

Table 4

High fat dairy products (mg kg^{-1} WW)

Specification	Cream (30-36% fat)		Creme Fraiche* (32% fat)	
	median	range	median	range
(%) H_2O	57.2	55.9 - 61.8	61.9	57.1 - 62.9
Al	0.23	< 0.1 - 0.53	0.46	0.29 - 0.70
B	< 0.03	< 0.03 - 0.07	< 0.03	
Ba	0.035	< 0.002 - 0.092	0.041	0.018 - 0.073
Be	0.0032	< 0.0005 - 0.0041	0.0015	< 0.0005 - 0.0033
Ca	823	657 - 1016	833	714 - 1077
Cd	< 0.002		< 0.002	
Ce	< 0.003		< 0.003	
Co	< 0.003		< 0.003	< 0.003 - 0.007
Cr	< 0.005	< 0.005 - 0.011	< 0.005	< 0.005 - 0.045
Cu	< 0.04		< 0.04	< 0.04 - 0.17
Fe	0.44	0.23 - 0.70	0.68	0.25 - 0.97
I	0.227	0.079 - 0.388	0.147	0.095 - 0.437
K	1048		1099	975 - 1223
La	< 0.002		< 0.002	
Li	0.0018	0.0002 - 0.0019	0.0037	0.0035 - 0.0038
Mg	71	56 - 77	67	59 - 204
Mn	0.008	< 0.004 - 0.029	0.089	< 0.004 - 0.362
Na	338	283 - 391	2073	1260 - 3312
Ni	0.015	< 0.004 - 0.041	0.008	< 0.004 - 0.035
P	666	614 - 750	656	575 - 980
S	241	169 - 260	243	241 - 248
Sc	< 0.004		< 0.004	
Si	0.69	0.25 - 0.95	1.02	0.92 - 1.13
Sr	0.164	0.064 - 0.304	0.222	0.173 - 0.420
Ti	0.015	< 0.01 - 0.021	0.024	0.023 - 0.025
V	0.005	< 0.004 - 0.014	< 0.004	
Y	0.004	0.002 - 0.005	0.003	< 0.002 - 0.006
Zn	2.61	2.43 - 3.75	2.30	1.02 - 2.80

* Creme Fraiche may contain additional herbs and salts.

contaminations were found. There is equal trace element intake, whether whole milk or skim milk is used, just coffee cream and full cream contain slightly less of the elements (Table 1*b*). From data presented in Tables 1*b* and 2*b* it can be concluded that 1 liter of milk or yoghurt easily meets the

Table 5

Austrian milk samples, natural fat and 3.5% fat conent, compared with commercially available full cream milk powder and infant formulas (mg kg^{-1} DW)

Element	Whole milk		Fullcream milk powder		Infant formulas	
	median	range	**median**	range	**median**	range
Al	**0.55**	<0.2 – 1.65	**1.92**	0.52 – 3.79	**1.10**	0.59 – 2.29
B	**0.84**	0.47 – 3.01	**0.83**	0.08 – 2.69	**0.41**	0.13 – 0.61
Ba	**0.44**	0.18 – 0.80	**0.46**	0.27 – 1.94	**0.30**	0.14 – 0.50
Be	**<0.003**	<0.003 – 0.005	**<0.003**	< 0.003	**<0.003**	<0.003 – 0.006
Ca	**11608**	7998 - 14336	**7754**	6773 - 9152	**3110**	**2820 - 5263**
Cd	**<0.002**	< 0.002	**<0.002**	<0.002 – 0.004	**0.0028**	<0.002 – 0.0136
Ce	**0.010**	<0.002 – 0.019	**0.002**	<0.002 – 0.011	**0.005**	<0.002 – 0.008
Co	**0.004**	<0.002 – 0.033	**0.042**	0.019 – 0.061	**0.027**	0.018 – 0.036
Cr	**0.14**	< 0.03 – 0.19	**< 0.03**	<0.03 – 0.04	**<0.03**	< 0.03
Cs	**0.003**	0.002 – 0.005	**0.041**	0.013 – 0.310	**0.005**	0.003 – 0.012
Cu	**0.28**	0.19 – 0.66	**0.24**	0.05 – 0.59	**3.66**	**2.64 – 4.82**
Fe	**1.39**	1.13 – 2.57	**32.1**	1.64 – **155.6**	**61.2**	**36.3 – 67.8**
I*	**2.56**	1.36 – 4.07	**0.97**	0.14 – 2.20	**2.03**	1.35 – 2.71
K	**11355**	9153 - 12901	**9067**	6981 - 10951	**4739**	3868 – 4969
La	**0.005**	< 0.002 – 0.009	**0.002**	<0.002 – 0.006	**0.004**	< 0.002 – 0.009
Li	**0.032**	0.004 – 0.148	**0.057**	0.024 – 0.095	**0.004**	<0.002 – 0.033
Mg	**842**	611 - 962	**693**	653 - 952	**375**	**351 – 450**
Mn	**0.15**	0.11 – 0.33	**0.34**	0.14 – 0.88	**0.56**	0.16 – 0.80
Mo	**0.049**	0.041 – 0.060	**0.260**	0.218 – 0.310	**0.113**	0.050 – 0.165
Na	**4189**	2879 - 4750	**2622**	2408 - 3942	**1274**	**1076 - 1835**
Ni	**0.02**	<0.01 – 0.21	**0.02**	<0.01 – 0.04	**0.05**	0.02 – 0.08
P	**7752**	5619 - 8933	**6060**	5712 - 7018	**2311**	**1888 - 3443**
Pb	**< 0.01**	< 0.01 – 0.03	**< 0.01**	< 0.01 – 0.012	**0.01**	< 0.01 – 0.05
Rb	**1.74**	0.94 – 3.11	**11.98**	6.40 – 35.56	**2.85**	1.37 – 5.83
S	**2490**	1665 - 2978	**2299**	861 - 2964	**1340**	1201 - 1522
Si	**6.5**	5.8 – 14.3	**10.8**	3.9 – 25.6	**8.8**	3.7 – 13.4
Sr	**1.98**	1.05 – 3.22	**3.16**	1.93 – 5.67	**1.23**	0.82 – 1.59
Ti	**0.14**	<0.06 – 0.16	**0.20**	< 0.06 – 0.26	**< 0.06**	< 0.06 – 0.13
V	**< 0.01**	< 0.01 – 0.02	**< 0.01**	< 0.01 – 0.11	**< 0.01**	< 0.01 – 0.02
Zn	**30.7**	22.0 – 42.5	**37.3**	13.9 – 85.2	**38.3**	32.9 – 53.9

* Element symbols given in italics refer to ICP-MS data.

DACh- recommended daily intake (RDI, 2013) of Ca (1000 mg for adults, 1200 mg for teenagers), P (700 mg for adults), Mg (350 mg for mend and 300 mg for women), and I (0.20 mg for men, 0.15 mg for non-pregnant women). In addition, 1 liter of milk supplies about half of the RDI for K (2000 mg) and Zn (10 mg for men, 7 mg for women), but just 1/10 of Cr and Mo, 1/20 of Cu, 1/50 of Fe and 1/100 of the RDI for Mn. The latter have to be ingested from other sources. Milk labelled to contain 1% cocoa improved the supply of Cu, Fe, and Mn, which frequently appear insufficient at too low vegetable consumption (Table 3), whereas the content determined in strawberry milk and acidophilus milk was within the same range as in plain milk. Similarly, differences between the content of elements in cream and créme fraiche are marginal (Table 4). Change to another animal source is almost of no effect to satisfy RDIs, but in case of iodine deficiency (particularly during pregnancy), sheep yoghurt is favourable, and soy drinks are completely unsuitable (Table 2*b*). Differences in levels of Li, Rb, Cs, Sr and Ba between cow, goat and sheep products could be due to variations in the composition of feed plants, which grow without further fertilization, particularly in areas where goats and sheep are kept (Sager 2014)).

Substition of dairy products by soymilk causes large changes in the pattern of intake of trace elements because they are similar to vegetable juices. The Ca content in soy drinks is sometimes labelled to make consumers believe that this drink is high in calcium, whereas the Ca contents in milk is not labelled even though it is higher. But one litre of soy drinks might contain the recommended daily intake for adults of Cr (0.03 - 0.10 mg), Cu (1-1.5 mg), Mg (350 mg), Mn (2-5 mg), Mo (0.5 mg), Na (550 mg) and P (700 mg; DACH recommendations 2013). On the other hand, remarkably high Ni should be of concern to allergics.

Austrian milk and globally traded milk powder and infant formulas

Multinational food enterprises produce spray-dried or freeze-dried milk powder and sell it on a global scale, particularly to feed children. Drying leads to the stabilization and lower weight, thus ensuring easier storage and transport, which helps to counteract fluctuations on the global market. Within an earlier study, milk powder and infant formulas packed in Ireland, the UK, South Africa, Kenya and Saudi Arabia, were sampled in Africa and analyzed by similar methods (Sager, McCulloch, Schoder 2017), and the results given in Table 5. It remains open whether differences versus Austrian milk were due to global variations in milk composition or to production technologies. Infant formulas are lower in Ca, K, Mg, Na, P and S, but intentionally fortified with Cu and Fe.

Separation of cream and whey

In milk, many elements hardly occur as free ions, but are bound to proteins or other ligands (Knowles et al. 2006). Precipitates of casein from sheep or goat milk enrich Al, Ba, Cd, Co, Cr, Cu, Fe, Mn, Pb and Zn, but not Mg, Ni and Sr (Coni et al. 1996). When products of descending fat content are placed in one table, most proportions of elements in fresh weight decrease parallel to the water and increasing fat content; just Fe and Al might have some lipophilicity.

Data of dairy products from other sources

In dairy products from Podlasie region (Poland), milk, cow-yoghurt, cream and butter contained many trace elements at equal levels found in this work (Cd, Cu, Fe, Pb), just cream had more Mn, and butter just 1/5 with respect to milk (Oprzadek et al. 2010). In Spain, cow milk and cow milk yoghurt contained all investigated trace elements in similar concentrations based on fresh weight than given in this work, but 10-fold more Fe and 5-fold more Al were reported (Llorent-Martinez et al. 2012). Even in 207 milk and yoghurt samples from South Korea, the levels of main elements (Ca, Mg, Na, K, P) in fresh weight were within the ranges found in Austria, except Fe, whose content was 100-fold higher (Khan et al. 2014).

Cow yoghurt from Turkey contained significantly more Co, Cr, Cu, Mg, Mn and Mo than samples from Austria, and only Fe and Zn were about the same (Güler, Şanal 2009).

In Spain, commercially available soy products also contained more Al, Ba, Cu, Fe, Mn, Mo, Ni and V, and about equal As, Cr, Pb, Zn (Llorent-Martinez et al. 2012) with respect to milk, as it is expected from plant origin food items.

CONCLUSIONS

Traded milk and dairy products have been proven to supply valuable trace elements (Ca, Mg, I) to consumers, and to be safe with respect to inorganic contaminants. Consumption of cream instead of skim milk lowers many ingested element loads, whereas trace element levels met in raw milk or skim milk are rather similar. In cow milk, physiologically active trace elements seem to occur on approximately the same levels. Some differences in the trace element patterns of cow, goat and sheep milk have been outlined. Elements of low physiological activity (e.g. rare earths) are close to or below detection limits, thus chances to trace the origin of milk according to the geological background seem minimal. White soy drinks are unsuitable for substituting mammalian milk because of significantly different composition. In particular, they supply less Ca and I, and more Ni.

REFERENCES

AMA Agrarmarkt Austria. Annual Report 2016. 1200 Vienna, Austria.

Anderson R.R. 1992. *Comparison of trace elements in milk of four species.* J. Dairy Sci., 75. 3050-3055.

Anke M., Angelow L.. Illing H.. Müller M.. & Glei M. 1993. *The ultra-trace element contents (Ni, Mo, Cd, Li, Rb, Pb) of milk and dairy products.* Milchwissenschaft, 48(10): 582. (in German)

Anonymous 2013. *Recommended Daily Intake* (Referenzwerte für die Nährstoffzufuhr) of the DGE. ÖGE. SGE and SVE. 1st edition. 5th reprint. DGE Bonn.

Codex Alimentarius Austriacus: available online at http://www.lebensmittelbuch.at/milch-und-milchprodukte

Coni E., Bocca A., Ianni D., Caroli S. 1995. *Preliminary evaluation of the factors influencing the trace element content of milk and dairy products.* Food Chem., 52. 123-130.

Coni E., Bocca A., Cappolelli P., Caroli S., Cavallucci C., Trabalza-Marinucci M. 1996. *Minor and trace element content in sheep and goat milk and dairy products.* Food Chem., 57(2). 253-260.

Güler Z., Şanal H. 2009. *The essential mineral concentration of Torba yoghurts and their wheys compared with yoghurt made with cows´. ewes´ and goats´ milks.* Int. J. Food Sci. Nutr., 60(2). 153-164.

Hódi K., Puskás-Preszner A., Czipa N., Kovacs B. 2009. *The elements´ distribution in the main and secondary product during processing of cow milk. Trace elements in the food chain.* Vol 3: *Deficiency or excess of trace elements in the environment as a risk of health.* pp. 78-82. M. Szilágyi and K. Szentmihalyi (eds.). Hungarian Academy of Sciences, Budapest.

Khan N., Choi J.Y., Nho E.Y., Hwang I.M., Habte G., Khan M.A., Park K.S., Kim. K.S. 2014. *Determination of mineral elements in milk products by inductively coupled plasma-optical emission spectrometry.* Anal. Lett., 47: 1606-1613.

Knowles S.O., Grace N.D., Knight T.W., Mc Nabb W.C., Lee J. 2006. *Reasons and means for manipulating the micronutrient composition of milk from grazing dairy cattle.* Anim. Feed Sci. Technol., 131: 154-167.

Laguna Paredes C. 2009. *Iodine in hens´eggs: Test of various analytical methods and determination of current iodine levels in eggs from Austria.* Master thesis. University of Natural Resources and Life Sciences, Vienna. (in German)

Llorent-Martinez E.J., Fernandez de Cordova M.L., Ruiz Medina A., Ortega Barrales P. 2012. *Analysis of 20 trace and minor elements in soy and dairy yogurts by ICPMS.* Microchem. J, 102: 23-27.

Oprzadek K., Gorska A., Olszewska E. 2010. *Trace elements: from raw cow milk to dairy products.* Fresen. Environ. Bull., 19(4): 585-588.

Sager M., Mittendorfer J. 1997. *Influence of milling or cutting procedures on trace element contents of plant samples.* Int. J. Environ. Anal. Chem., 67: 59-71.

Sager M. 2005. *Current elemental composisiton of meat, liver and kidneys from Austria.* Ernährung/Nutrition, 29(5): 199-206. (in German)

Sager M. 2011*a*. *Microwave- assisted digestion of organic materials with $KClO_3/HNO_3$ for the analysis of trace metals and non-metals.* Anal. Chem. Ind. J, 10(2): 101-108.

Sager M. 2011*b*. *Major and trace elements in hens´eggs from Austria.* Ernährung/Nutrition, 35(2): 53-58.

Sager M. 2012. *Major and trace elements in cheese for Austria.* Ernährung/Nutrition, 36: 149-159. (in German)

Sager M., Hobegger M. 2013. *Element contents in raw milk from 3 regions of Lower Austria.* Ernährung/Nutrition, 37(7/8): 277-290. (in German)

SAGER M. 2014. *Element and trace element contents in raw milk from Austria – comparison of alpine pasture with indoor keeping*. VDLUFA-Schriftenreihe, 70: 486-496. (in German)

SAGER M., CADAR O.A., SIMEDRU D. 2016. *Element and trace element contents of cow milk sampled in Western Romanian Carpathian and Alpine Areas*. Acta Oecologica Carpatica, 9: 199-204.

SAGER M., MCCULLOCH C.R., SCHODER D. 2017. *Element composition of Tanzanian milk*. Food Chem., (accepted for publication)