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Essential and non-mutagenic elements in raw ewe milk

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Original article

Abstract

The monitoring of metals and other chemical elements in the basic sources of diet, mainly for children, is very important for preventing health issues. The aim of this work was to determine the concentration of selected essential (Ca, K, Mg, Mo, Na, Zn) and non-mutagenic elements (Ag, Al, Ba, Li, Sb, Sr) in ewe milk from the Orava region in northern Slovakia. Twenty milk samples were analysed in June and August using an inductively-coupled plasma optical emission spectrometry. The differences in elements concentration between the seasonal periods were not significant ($p < 0.05$), except for lithium ($p < 0.05$). The essential elements concentration was within the recommended levels, while the non-mutagenic and potentially toxic metals consist was under the permissible limits. However, there were found very strong and significant relationships between the elements which may suggest the synergistic / additive or antagonistic effects of some elements.

Keywords

- macroelements
- microelements
- risk elements
- metals
- non-mutagenic elements
- ruminants
- ewe milk

Authors contributions

A – Conceptualization
B – Methodology
C – Formal analysis
D – Software
E – Investigation
F – Data duration
G – Visualization
H – Writing – original draft preperation
I – Writing, reviewing & editing
J – Project administration
K – Funding acquisition

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Conflict of interest

None declared.

Introduction

Ewe milk contains essential elements, vitamins, proteins, and other compounds important mainly for the children's health. However, except for these important compounds, they may contain also toxic or potentially toxic elements. Environmental contamination as a result of industrial activities is an important factor producing unwanted and often toxic chemical elements entering the food chain, including raw milk. These compounds transfer in the environment–animal–food system and cause human health issues. The studies are often published on metal monitoring in animal milk [1–8]. Analysis of 45 trace elements and 6 macroelements (Ca, K, Mg, Na, P, S) in cow milk revealed that there are clear differences between the organically and conventionally produced milk. The elevated levels of Mo in organic milk and reduced levels Ba, Eu, Mn, and Zn were found in comparison to conventional milk [9]. A higher concentration of Ca, Mg, K, and P is found in the milk of primiparous compared to multiparous cows. The breed also can influence the element content in milk, e.g. milk of Holstein-Friesian in comparison to Jersey cows seem to have the lower concentration of Ca, Mg, and P ions [10]. Organic dairy farms are characterized by lower concentrations of toxic heavy metals in whole raw milk compared with those from the conventional production system [11]. Long-term toxic metal consumption in milk can pose a serious health risk for children. The order of heavy metals in the cow milk was found as follows: Zn > As > Pb > Cr > Cu > Ni and lead exceeded the Codex limits [12]. Many studies are focused on the toxic elements which are mutagenic and also can cause cancer. Anyway, there are another important toxic metals and metalloids in the environment and food chain, including animal milk. Human activities affect the environmental quality and play a key role in the distribution of toxic metals in raw milk and contribute to Pb, As, and Cd contamination in animals and transfer to milk [13, 14]. The metals are often present in the environment and food in low quantities, but their combinations and mixtures may pose an elevated risk and can damage the human organism in low doses [15]. These interactions may indicate the regulation mechanisms and competition of these elements even at low exposure [16]. The relation between the metals in feed, water, and milk was reported [17]. However, no relations were found between the occurrence of toxic metals in soil, feed, and milk [18]. The elevated concentrations of metals (Zn, Fe, Cu) in the environment did not affect their concentrations in cow milk [19]. The season may also affect the concentrations of metals in milk with the highest influence during the summer season [20]. Concentrations of metals in ewe milk varied significantly with different seasons [21]. The concentration of toxic metals in milk increases with the increasing age of the animals [22]. Lithium and strontium are involved in calcium metabolism. Lithium contents in the milk products ranged from 0.01 to 0.50 mg/kg, calcium from 1010 to 2020 mg/kg, and strontium from 0.21 to 0.79 mg/kg [23].

Milk consumption is important mainly for children's health. Therefore, this study aimed to analyze the occurrence of twelve essential and minor, non-mutagenic risk elements in the raw ewe milk from northern Slovakia. The relationships between the elements in the ewe milk were also expressed.

Materials and methods

Milk sample collection

The milk samples were collected in the Orava region, northern Slovakia, considered as a region with an undisturbed environment [24]. Twenty lactating ewes, 7 years old, were randomly selected from the sheep herds of 400 animals (Tsigai breed). The milk was collected two times by individual hand milking in the spring and summer seasons (June and August). Approximately 500 mL of milk were collected from each ewe in both periods, in total 20 milk samples. Samples were stored in PET bottles at –20°C until analysis.

Sample analysis

The following 12 elements were analyzed in all milk samples: Ag, Al, Ba, Ca, K, Li, Mg, Mo, Na, Sb, Sr, and Zn. The content of selected elements was determined in raw milk samples by inductively-coupled plasma optical emission spectrometry (ICP-OES). As a first step, the pre-analytical procedure was made. All the chemicals used during the sample preparation were highly pure. Until the sample processing, they were stored in a freezer at –20°C. The weight of the experimental samples ranged from 0.5 to 2.0 g and was reflected in measurement. The samples were mineralized in the high-performance microwave digestion system Ethos UP (Milestone Srl, Sorisole, BG, Italy) in a solution of 5 ml HNO_3 ≥ 69.0% (TraceSELECT®, Honeywell Fluka, Morris Plains, USA), 1 ml H_2O_2 ≥ 30%, for trace analysis (Sigma Aldrich, Saint–Louis, Missouri, USA) and 2 ml of ultrapure water (18.2 MΩ cm^{-1}; 25°C, Synergy UV, Merck Millipore, France). Samples, including the blank sample, were digested according to a method for animal tissue developed and recommended by the manufacturer to achieve the most reliable results. The method consists of heating and cooling phases. During the heating stage, the samples were warmed to 200°C for 15 min and this temperature was maintained for another 15 min. Afterward, during the cooling phase, the samples underwent active cooling for 15 min to reach the temperature of 50°C. The digests were filtered through the VWR Quantitative filter paper 454 (particle retention 12–15 µm) (VWR International, Leuven, France) into the volumetric flasks and filled up with ultrapure water to a volume of 50 mL. Analysis of the elements was carried out using an inductively coupled plasma–optical emission spectrometer (ICP OES 720, Agilent Technologies Australia (M) Pty Ltd.) with axial plasma configuration and with auto140 sampler SPS-3 (Agilent Technologies, Switzerland). Details of the instrumental operating conditions are listed in Table 1 and Table 2.

Table 1. The operating parameters of determination of elements by ICP-OES

Parameter	Value
RF Power [kW]	1.30
Plasma flow [L/min]	15.0
Auxiliary flow [L/min]	1.50
Nebulizer flow [L/min]	0.85
Replicated read time [s]	5.00
Instrument stabilization [s]	15
Sample uptake delay [s]	25
Pump rate [rpm]	15
Rinse time [s]	10

Table 2. The wavelenghts for individual elements

Element	[λ/nm]	Element	[λ/nm]
Ag	328.068	Mg	383.829
Al	167.019	Mo	204.598
Ba	455.403	Na	589.592
Ca	315.887	Sb	206.834
K	766.491	Sr	407.771
Li	670.783	Zn	206.200

Quality assurance

The limits of detection (LOD) and limits of quantification (LOQ) were evaluated for the validation of the analytical method (Table 3). In the experiment, the multielement standard solution V for ICP (Sigma-Aldrich Production GmbH, Switzerland) was used. LOD in digest was calculated as three times the standard deviation of the sample blank relative to the slope of the analytical curve. LOQ was calculated as 10 times the standard deviation of the sample blank relative to the slope of the analytical curve.

Table 3. LOD and LOQ values for analyzed elements in milk [µg/kg]

	Ag	Al	Ba	Ca	K	Li
LOD	0.30	0.20	0.03	0.01	0.30	0.06
LOQ	1.00	0.67	0.10	0.03	1.00	0.20
	Mg	**Mo**	**Na**	**Sb**	**Sr**	**Zn**
LOD	0.01	0.50	0.15	2.00	0.01	0.20
LOQ	0.03	1.67	0.50	6.67	0.03	0.67

LOD – limit of determination; LOQ – limit of quantification

Based on the obtained LOD limits, LOQ limits according to the needs of Commission Regulation (EC) no. 1881/2006 were obtained. LOQ limits were recalculated from mg/l (LOD) to mg/kg based on the sample weight and the final volume of the digest. The quality control (QC) during measurement was ensured by a parallel analysis of at least one sample and the method calibration was controlled before every measurement by the control sample from the calibration solution of certified reference material (CRM). The accuracy of the method was verified using the CRM (CRM–ERM CE278 K, Sigma-Aldrich Production GmbH, Switzerland).

Statistical analysis

Statistical analysis of the data was performed using IBM SPSS Statistic 26 (IBM, USA). Differences in concentrations of the analyzed elements in milk between the seasons were compared by the ANOVA and Student's t-test. All data were expressed as mean and standard deviation. The half-value of the LOD was used for values below the LOD for statistical calculations. The relationships between the levels of individual metals in the milk of ewes were calculated using Pearson's correlation analysis. A probability level of $p < 0.05$ was considered statistically significant. The strength of the correlation for is expressed as follows: $r = 0.0–0.2$ – very weak dependence, $r = 0.2–0.4$ – weak dependence, $r = 0.4–0.6$ – moderate dependence, $r = 0.6–0.8$ – strong dependence, $r = 0.8–1$ – very strong dependence.

Results and discussion

The concentrations of essential elements in raw ewe milk were within the recommended levels. The non-mutagenic and potentially toxic metals concentrations were under the permissible limits (Table 4).

Table 4. Concentrations of elements in ewe milk in June and August [mg/kg]

Element	June			August		
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum
Ag	0.0017 ± 0.002	ND	0.0049	0.0010 ± 0.002	ND	0.0073
Al	0.0259 ± 0.059	ND	0.0791	0.0114 ± 0.035	ND	0.1135
Ba	0.1602 ± 0.042	0.0831	0.2329	0.1794 ± 0.050	0.0877	0.2533
Ca	1084.88 ± 170.41	732.40	1291.2	1230.82 ± 259.08	788.20	1675.70
K	623.73 ± 72.82	482.33	721.40	657.76 ± 112.10	438.38;	813.58
Li	0.0085 ± 0.004	0.0011	0.0139	0.0130 ± 0.004*	0.0070	0.0197
Mg	120.27 ± 16.84	87.62	142.77	114.54 ± 17.61	90.47	144.66
Mo	0.0048 ± 0.01	ND	0.0164	0.0051 ± 0.012	ND	0.0398
Na	547.85 ± 164.21	274.00	732.40	760.03 ± 500.13	218.80	1644.70
Sb	ND	ND	ND	ND	ND	ND
Sr	0.5062 ± 0.124	0.2493	0.6673	0.5865 ± 0.174	0.3254	0.8987
Zn	3.64 ± 1.040	2.26	5.88	3.85 ± 0.650	2.95	4.88

SD – standard deviation; ND – not detected; $^{*}p < 0.05$

Cow milk is characterized by the least variations in the contents of elements than sheep milk [25] and is affected by feed (i.e. grazing in the industrial areas), breed, individuality, season, and lactation stages [26]. The calcium concentration in ewe milk was higher in summer. Similar results were found in a different region of Slovakia, Tulcik, where Ca concentrations in spring were significantly lower than those in summer or autumn [18]. Our results support also the conclusion of experiments with ewes, where the total calcium content tended to increase throughout the milking season with the lowest concentration in February and higher concentration in June [27] or in the late stage of lactation [28]. Our results show the lower average Ca concentrations (1084.88 and 1230.82 mg/kg in spring and summer, respectively) in ewe milk than found in other analyses [27, 29–32]. The contents of Ca in our analyses are close to those in cows or goats [29, 33, 34]. Increasing calcium concentrations in milk are probably related to the grazing period [35] and feed quality [36]. However, there are reports in the literature, that the season has no effect on Ca levels in milk [37, 38]. Calcium constituted the largest part of all elements in both seasons with following order: Ca > K > Na > Mg > Zn > Sr > Ba > Al > Li > Mo > Ag > Sb in June, and Ca > Na > K > Mg > Zn > Sr > Ba > Li > Al > Mo > Ag > Sb in August. Opposite to calcium, the magnesium concentrations were lower in summer than in the spring season. However, this difference was not significant. The levels of Mg in ewe milk is much higher than in breast milk with a wide range of 15 to 64 mg/l [39], 98 to 170.5 mg/kg [40] but lower than that of the goats [41]. Except of the Ca and Mg, other macrominerals occurring and often analysed in the milk of mammals are P, K, and Na [42]. The concentration of K was similar in both seasons. The higher concentration of Na was analysed in summer than in spring. The decreased level of sodium during lactation was found in human lactation [42]. The highest concentrations of Na and Ca were found in sheep milk in comparison with human, goat, cow, and mare milk [41]. The metals ingested by dairy animals can be transferred to milk through the blood [43]. Molybdenum analyses in ewe milk are sparse. Mo is an essential dietary element. The median Mo intake from dietary supplements is about 23 and 24 µg/day for men and women, respectively. Exposure to Mo in industrial areas with mining activities can be significant [44]. Increased intake of Mo by lactating ewes can affect the metabolism of copper [45]. Mo concentrations in ewe milk from Orava (0.0048–0.0051 mg/kg) were very low and much lower than in ewe milk published by other authors (0.14 mg/kg) [45]. The toxic metals are unwanted in human food and particularly in milk which is considered as a basic diet for children. Several non-essential trace elements were found in ewe and goat milk. Chronic aluminium intake can lead to damage of the nervous system and adverse effects of non-occupational aluminium exposure on renal functions are well documented [46]. In our experiments, the Al concentrations in milk were very low in both seasons with lower values in summer than in spring. Similar concentrations (28.01 µg/kg) were found in raw cow milk in Turkey [47]. The concentrations of Al in ewe milk (5.65 mg/kg) and goat milk (5.04 mg/kg) in Turkey were much higher than in our experiments [48]. Similarly, higher Al concentrations were found in sheep and goat milk in Italy (0.85–3.87 µg/g) [49] and other study in sheep milk (0.5–1.8 mg/kg) [29]. The elevated Al content in animal milk may be the result of using the aluminium equipment (i.e. containers) in milking process. The milking equipment in the observed farm is made of steel and aluminium leakage is not expected. Despite the fact, that milk is not contaminated by aluminium, its levels can be increased by local environmental contamination during the phase of cheese ripening [49]. Zinc is an essential element in humans important in metabolism and enzyme function but can be toxic in higher doses [50]. In this work, the Zn concentrations in ewe milk were stable during the observed seasons and we found only minor differences between the spring and summer seasons. Similar concentrations of Zn in ewe milk during the late stage of lactation were found in a different area of Slovakia, Horná Nitra, which is considered a region with a slightly disturbed environment [40]. In cow milk from Turkey, zinc was the element with the highest frequency of occurrence in concentrations of 263.60 µg/kg [47]. This concentration is more than ten times lower than in our experiments. However, higher Zn concentrations were described in sheep and goat milk (21.2–26.0 and 16.8–19.3 mg/kg, respectively) [49] and ewes (4.66–11.80 mg/kg) [51]. Other studies show various data on the zinc concentrations in milk of different animal species [29, 41–42, 51–52]. Zinc content in cow milk from the same area of Slovakia, Orava, was higher (40.2 mg/kg in spring and 30.3 mg/kg in autumn) than that in this study [19]. Barium is a highly toxic metal affecting the passive efflux of intracellular potassium ions. Cardiac arrhythmias and muscle weakness are the results of barium poisoning [53]. In ewe and goat milk, the barium and strontium concentrations are found to be higher than in cow milk [49]. In our case, Ba levels were lower than in other studies [48–49]. There were no significant seasonal differences in Ba levels in ewe milk from the Orava region. The lower concentrations of Ba were found in cow milk and ranged from 62.20–105.80 µg/l [54]. Strontium and lithium may represent the important milk minor elements. Strontium is chemically and biologically similar to calcium. Sr and Li are able to modulate calcium metabolism and vice versa [55,56]. Moreover, barium and strontium are deposited in the hydroxyapatite structure of bones [57] which is the main site of calcium incorporation. The data found regarding the Sr concentration in milk are contradictory in the literature. An important finding is that the transfer index of Sr from blood to milk is higher than for other toxic metals like cadmium, lead, chromium, arsenic [43]. In this work, the strontium was found in a concentration of 0.5062 mg/kg in spring and 0.5865 mg/kg in summer and the differences were not significant. The similar concentrations in cow milk in Turkey (378.90–984.30 µg/l) [54]. The lower concentration (0.04 mg/kg) was found in cow milk in areas irrigated with wastewater [43]. On the other hand, higher Sr concentrations were found in the ewe (4.72–6.24 µg/g) and goat (4.60–4.80 µg/g) milk [49]. The concentrations of Sr in our work do not pose a health risk for consumers. The different situation in seasonal differences was recorded for lithium. The significantly higher Li concentration in raw ewe milk was found in summer. The tolerable daily intake of Li is 0.02 mg/kg bw in humans [58]. In cow milk, the lithium concentrations were in the wide range of 0.001–38.80 µg/l [54]. The concentrations of Li in this work are within this range. In milk products, the Li levels (0.07 mg/kg) were higher than in our experiments [56]. The data of Li occurrence in the milk of various mammals published earlier were as follows: guinea pig 0.034 ppm, cow 0.024 ppm, horse 0.015 ppm, and human 0.0065 ppm [59]. Lithium chloride used for induced conditioned taste aversion is considered safe in ruminants because of low concentrations of Li found in eces, urine, and milk [60]. The source of antimony toxicity may be occupational, medical, or environmental exposure [61,62]. In this work, we were not able to detect Sb in any milk sample in both seasons. Sb concentrations in ewe and goat milk (2.19 and 3.47 mg/kg, respectively) were published [48]. Silver is the minor metal found in animal and human milk and is considered non-essential for humans [63]. Very low concentrations were found in both seasons with no significant difference. More than 100 times higher concentrations were found in ewe and goat milk (0.286 and 0.25 mg/kg, respectively) [48]. The studies on the silver in milk are rare. The distribution of silver nanoparticles was found to distribute to milk in mice depending on the size of particles [64]. However, toxic effects were found after peroral intake of silver [65].

The possible interactions of analysed elements show the correlation analysis. The results of the correlation analyses are summarized in Tables 5 and 6.

Table 5. The correlation analysis of the elements in ewe milk in June

	Al	Ba	Ca	K	Li	Mg	Mo	Na	Sr	Zn
Ag	−0.300	−0.215	0.096	−0.549	0.579	−0.135	0.054	0.322	−0.078	−0.288
p	0.400	0,550	0.791	0.100	0.079	0.709	0.882	0.363	0.830	0.419
Al		0.133	0.168	0.329	−0.155	0.092	−0.218	−0.156	0.176	0.678*
p		0.713	0.643	0.363	0.670	0.800	0.545	0.668	0.628	0.031
Ba			0.360	0.486	−0.403	0.526	−0.109	0.001	0.942***	0.542
p			0.307	0.154	0.249	0.118	0.763	0.999	0.0009	0.106
Ca				0.513	0.526	0.910***	0.184	0.740*	0.377	0.508
p				0.130	0.118	0.0009	0.611	0.014	0.283	0.133
K					−0.355	0.653*	−0.266	0.014	0.328	0.606
p					0.314	0.041	0.457	0.969	0.355	0.063
Li						0.239	0.445	0.739*	−0.218	−0.151
p						0.505	0.198	0.015	0.545	0.676
Mg							0.038	0.535	0.476	0.620
p							0.917	0.111	0.164	0.056
Mo								0.287	0.009	−0.160
p								0.421	0.981	0.658
Na									−0.011	−0.138
p									0.977	0.703
Sr										0.593
p										0.071

p – significance of correlation coefficient; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table 6. The correlation analysis of the elements in ewe milk in August

	Al	Ba	Ca	K	Li	Mg	Mo	Na	Sr	Zn
Ag	−0.137	0.161	0.050	0.247	−0.024	0.207	0.943***	−0.063	0.059	−0.139
p	0.707	0.657	0.891	0.491	0.948	0.565	0.0009	0.863	0.871	0.702
Al		0.515	0.603	0.325	0.167	0.309	−0.136	−0.250	0.630	0.552
p		0.128	0.065	0.359	0.645	0.385	0.708	0.486	0.051	0.098
Ba			0.745*	0.696*	0.524	0.646*	0.273	−0.106	0.807**	0.562
p			0.013	0.025	0.120	0.044	0.446	0.771	0.005	0.091
Ca				0.919***	−0.076	0.779**	0.066	−0.700*	0.988***	0.901***

	Al	Ba	Ca	K	Li	Mg	Mo	Na	Sr	Zn
p				0.0009	0.836	0.008	0.856	0.024	0.0009	0.0009
K					−0.211	0.886^{***}	0.225	-0.724^{*}	0.906^{***}	0.749^{*}
p					0.558	0.001	0.531	0.018	0.0009	0.013
Li						−0.215	0.205	0.688^{*}	0.006	−0.056
p						0.551	0.569	0.028	0.986	0.878
Mg							0.108	−0.491	0.826^{**}	0.564
p							0.767	0.149	0.003	0.089
Mo								0.013	0.070	−0.068
p								0.554	0.876	0.312
Na									−0.597	-0.671^{*}
p									0.068	0.034
Sr										0.863^{**}
p										0.001

p – significance of correlation coefficient; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Significant correlation relationships were found between the elements. Very strong positive correlation between Al:Zn ($p < 0.05$), Ba:Sr ($p < 0.001$), Ca:Mg ($p < 0.001$), Ca:Na ($p < 0.05$), K:Mg ($p < 0.05$), Li:K ($p < 0.05$) were found in June and between Ag:Mo ($p < 0.001$), Ba:Ca ($p < 0.05$), Ba:K ($p < 0.05$), Ba:Mg ($p < 0.05$), Ba:Sr ($p < 0.01$), Ca:K ($p < 0.001$), Ca:Mg ($p < 0.01$), Ca:Sr ($p < 0.001$), Ca:Zn ($p < 0.001$), K:Mg ($p < 0.001$), K:Sr ($p < 0.001$), K:Zn ($p < 0.05$), Li:Na ($p < 0.05$), Mg:Sr ($p < 0.01$) in August. Moreover, very strong negative correlations were found between Na:-Ca ($p < 0.05$), Na:K ($p < 0.05$), Na:Zn ($p < 0.05$) in August. The significant positive relationships between Al and Zn were found also in goat milk and Zn concentration was affected by the stage of lactation [26]. In our work, the stage of lactation did not affect significantly the Zn content in ewe milk. Interactions between Al and Ca in bones and kidneys were described [66]. However, we cannot confirm the relationship between these elements in milk. On the other hand, the relationships between Al and Ca, and Ca, Sr, Li, Ba in the bone metabolism and structure and muscle contractility are known [55–56, 67–69]. In the milk, relationships were also found between these elements. Similar results were found for Na and Ca in milk. Both elements are involved in cardiovascular diseases and osteoporosis [70]. Aluminium interacts also with Ca and Mg affecting the nervous system. The decrease in calcium and magnesium intake may lead to aluminum-induced degenerative nervous diseases [66]. A positive correlation between Ca and Mg in blood plasma [71] indicates the possible relationships between these elements in other organs and fluids. In fact, in this work, the significant correlations between Ca:Mg were calculated in both seasons. Lithium positively correlated with K and Na but not with Sr as previously found in cow milk [54]. The barium interactions with potassium channels are well known [72] and correlations between Ba and K were found in this study in the spring season.

Conclusions

The ewe milk from the northern part of Slovakia in the Orava region contains essential elements in the normal range. The risk, but non-mutagenic elements were also in low concentrations which do not pose risk for the consumer. There were very strong and significant relationships between the elements which may suggest the synergistic / additive or antagonistic effects of some elements. The monitoring of metals and other chemical elements in the basic sources of diet, mainly for children, is very important for preventing health issues.

References

[1] Simsek O, Gültekin R, Öksüz O, Kurultay S. The effect of environmental pollution on the heavy metal content of raw milk. Nahrung. 2000;44(5):360–363. https://doi.oerg/ 10.1002/1521-3803(20001001)44:5<360::AID-FOOD360>3.0.CO;2-G.

[2] Rahimi E. Lead and cadmium concentrations in goat, cow, sheep, and buffalo milks from different regions of Iran. Food Chemistry. 2013;136(2):389–391. https://doi.org/ 10.1016/j.foodchem.2012.09.016.

[3] Zhou X, Qu X, Zhao S, Wang J, Li S, Zheng N. Analysis of 22 elements in milk, feed, and water of dairy cow, goat, and buffalo from different regions of China. Biological Trace Element Research. 2017;176(1):120–129. https://doi.org/ 10.1007/s12011-016-0819-8.

[4] Akele ML, Abebe DZ, Alemu AK, Assefa AG, Madhusudhan A, de Oliveira RR. Analysis of trace metal concentrations in raw cow's milk from three dairy farms in North Gondar. Ethiopia: chemometric approach. Environmental Monitoring and Assessment. 2017;189(10):499. https://doi.org/ 10.1007/s10661-017-6203-0.

[5] 5. González-Montaña JR, Senís E, Alonso AJ, Alonso ME, Alonso MP, Domínguez JC. Some toxic metals (Al, As, Mo, Hg) from cow's milk raised in a possibly contaminated area by different sources. Environmental Science and Pollution Research. 2019;26(28):28909–28918. https://doi.org/ 10.1007/s11356-019-06036-7.

[6] Toman R, Psenkova M, Tancin V. The occurrence of eleven elements in dairy cow´s milk, feed and soil from three different regions of Slovakia. Potravinarstvo Slovak Journal of Food Science. 2020;14:967–977. https://doi.org/10.5219/1461.

[7] Antunović Z, Mioč B, Klir Ž, Širić I, Držaić V, Lončarić Z, Bukvić G, Novoselec J. Concentrations of mercury and other elements in ewes' milk: Effect of lactation stage. Chemosphere. 2020;261:128128. https://doi.org/10.1016/j.chemosphere.2020.128128.

[8] Boudebbouz A, Boudalia S, Bousbia A, Habila S, Boussadia MI, Gueroui Y. Heavy metals levels in raw cow milk and health risk assessment across the globe: A systematic review. Science of the Total Environment. 2021;751:141830. https://doi.org/10.1016/j.scitotenv.2020.141830.

[9] Hermansen JE, Badsberg JH, Kristensen T, Gundersen V. Major and trace elements in organically or conventionally produced milk. Journal of Dairy Research. 2005;72(3):36–368. https://doi.org/ 10.1017/S0022029905000968.

[10] Manuelian CL, Penasa M, Visentin G, Zidi A, Cassandro M, De Marchi M. Mineral composition of cow milk from multibreed herds. Animal Science Journal. 2018;89(11):1622–1627. https:// 10.1111/asj.13095.

[11] Zwierzchowski G, Ametaj BN. Minerals and heavy metals in the whole raw milk of dairy cows from different management systems and countries of origin: A meta-analytical study. Journal of Agricultural and Food Chemistry. 2018;66(26):6877–6888. https://doi.org/ 10.1021/acs.jafc.8b00904.

[12] Castro-González NP, Calderón-Sánchez F, Pérez-Sato M, Soní-Guillermo E, Reyes-Cervantes E. Health risk due to chronic heavy metal consumption via cow's milk produced in Puebla, Mexico, in irrigated wastewater areas. Food Additives and Contaminants. Part B, Surveillance. 2019;12(1):38–44. https://doi.org/ 10.1080/19393210.2018.1520742.

[13] 13. Kazi TG, Jalbani N, Baig JA, Kandhro GA, Afridi HI, Arain MB, Jamali MK, Shah AQ. Assessment of toxic metals in raw and processed milk samples using electrothermal atomic absorption spectrophotometer. Food and Chemical Toxicology. 2009;47(9):2163–2169. https://doi.org/ 10.1016/j.fct.2009.05.035.

[14] Zhou X, Qu X, Zheng N, Su C, Wang J, Soyeurt H. Large scale study of the within and between spatial variability of lead, arsenic, and cadmium contamination of cow milk in China. Science of the Total Environment. 2019;650:3054–3061. https://doi.org/ 10.1016/j.scitotenv.2018.09.094.

[15] Anyanwu BO, Ezejiofor AN, Igweze ZN, Orisakwe OE. Heavy metal mixture exposure and effects in developing nations: An update. Toxics. 2018;6(4):65. https://doi.org/ 10.3390/toxics6040065.

[16] López Alonso M, Prieto Montaña F, Miranda M, Castillo C, Hernández J, Luis Benedito J. Interactions between toxic (As, Cd, Hg and Pb) and nutritional essential (Ca, Co, Cr, Cu, Fe, Mn, Mo, Ni, Se, Zn) elements in the tissues of cattle from NW Spain. Biometals. 2004;17(4):389–397. https://doi.org/ 10.1023/b:biom.0000029434.89679.a2.

[17] Zhou X, Qu X, Zhao S, Wang J, Li S, Zheng N. Analysis of 22 elements in milk, feed, and water of dairy cow, goat, and buffalo from different regions of China. Biological Trace Element Research. 2017;176(1):120–129. https://doi.org/10.1007/s12011-016-0819-8.

[18] 18. Toman R, Psenkova M, Tancin V. The occurrence of eleven elements in dairy cow´s milk, feed, and soil from three different regions of Slovakia. Potravinarstvo Slovak Journal of Food Science. 2020;14:967–977. https://doi.org/10.5219/1461.

[19] Pšenková M, Toman R, Tančin V. Concentrations of toxic metals and essential elements in raw cow milk from areas with potentially undisturbed and highly disturbed environment in Slovakia. Environmental Science and Pollution Research. 2020;27(21):26763–26772. https://doi.org/10.1007/s11356-020-09093-5.

[20] Tahir M, Iqbal M, Abbas M, Tahir MA, Nazir A, Iqbal DN, Kanwal Q, Hassan F, Younas U. Comparative study of heavy metals distribution in soil, forage, blood and milk. Acta Ecologica Sinica. 2017;37(3):207-212. https://doi.org/10.1016/j.chnaes.2016.10.007.

[21] Najarnezhad V, Akbarabadi M. Heavy metals in raw cow and ewe milk from north-east Iran. Food Additives and Contaminants. Part B: Surveillance. 2013;6:158–162. https://doi.org/ 10.1080/19393210.2013.777799.

[22] Najarnezhad V, Jalilzadeh-Amin G, Anassori E, Zeinali V. Lead and cadmium in raw buffalo, cow and ewe milk from west Azerbaijan, Iran. Food Additives and Contaminants. Part B: Surveillance. 2015;8(2):123–127. https://doi.org/ 10.1080/19393210.2015.1007396.

[23] Nabrzyski M, Gajewska R. Content of strontium, lithium and calcium in selected milk products and in some marine smoked fish. Nahrung. 2002;46(3):204-208. https://doi.org/10.1002/1521-3803(20020501)46:3<204::aid-food204>3.0.co;2-8.

[24] Lieskovska Z, Micuda J. State of the Environment Report – Slovak Republic 2019. Bratislava. Banská Bystrica: Ministry of Environment of the Slovak Republic. Slovak Environmental Agency; 2019.

[25] Rincón F, Moreno R, Zurera G, Amaro M. Mineral composition as a characteristic for the identification of animal origin of raw milk. Journal of Dairy Research. 1994;61(1):151–154. https://doi.org/10.1017/S0022029900028144.

[26] Park YW, Chukwu HI. Trace mineral concentrations in goat milk from French-Alpine and Anglo-Nubian breeds during the first 5 months of lactation. Journal of Food Composition and Analysis. 1989;2(2):161–169. https://doi.org/10.1016/0889-1575(89)90077-X.

[27] Abilleira E, Virto M, Nájera AI, Salmerón J, Albisu M, Pérez-Elortondo FJ, Ruiz de Gordoa JC, de Renobales M, Barron LJ. Effects of seasonal changes in feeding management under part-time grazing on the evolution of the composition and coagulation properties of raw milk from ewes. Journal of Dairy Science. 2010;93(9):3902–3909. https://doi.org/10.3168/jds.2009-2983.

[28] Rako A, Kalit MT, Kalit S. Effect of sheep's milk composition on strength and syneresis of rennet-induced milk gel during lactation. Food Technology and Biotechnology. 2019;57(3):426–433. https://doi.org/ 10.17113/ftb.57.03.19.6218.

[29] Park YW, Juárez M, Ramos M, Haenlein GFW. Physico-chemical characteristics of goat and sheep milk. Small Ruminant Research. 2007;68(1–2):88–113. https://doi.org/10.1016/j.smallrumres.2006.09.013.

[30] Pilarczyk R, Wójcik J, Czerniak P, Sablik P, Pilarczyk B, Tomza-Marciniak A. Concentrations of toxic heavy metals and trace elements in raw milk of Simmental and Holstein-Friesian cows from organic farm. Environmental Monitoring and Assessment. 2013;185(10):8383–8392. https://doi.org/ 10.1007/s10661-013-3180-9.

[31] Toffanin V, Penasa M, McParland S, Berry DP, Cassandro M, De Marchi M. Genetic parameters for milk mineral content and acidity predicted by mid-infrared spectroscopy in Holstein-Friesian cows. Animals. 2015;9(5):775–780. https://doi.org/ 10.1017/S1751731114003255.

[32] Capcarova M, Binkowski LJ, Stawarz R, Schwarczova L, Massanyi P. Levels of essential and xenobiotic elements and their relationships in milk available on the Slovak market with the estimation of consumer exposure. Biological Trace Elements Research. 2019;188(2):404–411. https://doi.org/ 10.1007/s12011-018-1424-9.

[33] Chandan RC, Attaie R, Shahani KM. Nutritional aspects of goat milk and its products. Proceedings of the Fifth International Conference on Goats vol. II, part II; 1992 New Delhi, India. New Delhi: Indian Council of Agricultural Research Publishers; 1992.

[34] Chia J, Burrow K, Carne A, McConnell M, Samuelsson L, Day L, Young W, Bekhit AAE. Minerals in sheep milk. In: Watson RR, Collier RJ, Preedy VR, editors. Nutrients in Dairy and their Implications on Health and Disease. Academic Press; 2017: p. 345–362.

[35] Nájera AI, Barron LJR, Ribeiro P, Pèlissier F, Abilleira E, Pérez-Elortondo FJ, Albisu M, Salmerón J, Ruiz de Gordoa JC, Virto M, Oregui L, Ruiz R, de Renobales M. Seasonal changes in the technological and compositional quality of ewe's raw miles from commercial flocks under part-time grazing. Journal of Dairy Research. 2009;76(3):301–307. https:/doi.org/ 10.1017/S0022029909004178.

[36] Inglingstad RA, Steinshamn H, Dagnachew BS, Valenti B, Criscione A, Rukke EO, Devold TG, Skeie SB, Vegarud GE. Grazing season and forage type influence goat milk composition and rennet coagulation properties. Journal of Dairy Science. 2014;97(6):3800–3814. https://doi.org/https://doi.org/10.3168/jds.2013-7542.

[37] Lin Y, O'Mahony JA, Kelly AL, Guinee TP. Seasonal variation in the composition and processing characteristics of herd milk with varying proportions of milk from spring-calving and autumn-calving cows. Journal of Dairy Research. 2017;84(4):444–452. https://doi.org/10.1017/S0022029917000516.

[38] Chassaing C, Sibra C, Verbič J, Harstad OM, Golecký J, Martin B, Ferlay A, Constant I, Delavaud C, Hurtaud C, Pongrac VŽ, Agabriel C. Mineral, vitamin A and fat composition of bulk milk related to European production conditions throughout the year. Dairy Science and Technology. 2016;96:715–733. https://doi.org/10.1007/s13594-016-0300-7.

[39] Dórea JG. Magnesium in human milk. Journal of the American College of Nutrition. 2000;19(2):210–219. https://doi.org/ 10.1080/07315724.2000.10718919.

[40] Pšenková M, Toman R. Determination of essential and toxic elements in raw sheep's milk from area of Slovakia with environmental burden. Biological Trace Element Research. 2021;199(9):3338–3344. https://doi.org/ 10.1007/s12011-020-02452-w.

[41] Pietrzak-Fiećko R, Kamelska-Sadowska AM. The comparison of nutritional value of human milk with other mammals' milk. Nutrients. 2020;12(5):1404. https://doi.org/ 10.3390/nu12051404.

[42] Zwierzchowski G, Ametaj BN. Mineral elements in the raw milk of several dairy farms in the province of Alberta. Foods. 2019;8(8):345. https://doi.org/10.3390/foods8080345.

[43] Numa Pompilio CG, Francisco CS, Marco Tulio FM, Sergio Samuel SM, Fernanda Eliza GJ. Heavy metals in blood, milk and cow's urine reared in irrigated areas with wastewater. Heliyon. 2021;7:e06693. https://doi.org/10.1016/j.heliyon.2021.e06693.

[44] Barceloux DG. Molybdenum. Journal of Toxicology: Clinical Toxicology. 1999;37(2):231–237. https://doi.org/10.1081/CLT-100102422.

[45] Wittenberg KM, Devlin TJ. Effects of dietary molybdenum on productivity and metabolic parameters of lactating ewes and their offspring. Canadian Journal of Animal Science. 1988;68(3):769–778. https://doi.org/10.4141/cjas88-086.

[46] Krewski D, Yokel RA, Nieboer E, Borchelt D, Cohen J, Harry J, Kacew S, Lindsay J, Mahfouz AM, Rondeau V. Human health risk assessment for aluminium, aluminium oxide, and aluminium hydroxide. Journal of Toxicology and Environmental Health. Part B: Critical Reviews. 2007;Suppl 1:1–269. https://doi.org/10.1080/10937400701597766.

[47] Totan FE, Filazi A. Determination of some element levels in various kinds of cow's milk processed in different ways. Environmental Monitoring and Assessment. 2020;192(2):112. https://doi.org/10.1007/s10661-020-8088-6.

[48] Sanal H, Güler Z, Park YW. Profiles of non-essential trace elements in ewe and goat milk and their yoghurt, torba yoghurt and whey. Food Additives and Contaminants Part B Surveillance. 2011;4(4):275–281. https://doi.org/10.1080/19393210.2011.617520.

[49] Coni E, Bocca B, Caroli S. Minor and trace element content of two typical Italian sheep dairy products. Journal of Dairy Research. 1999;66(4):589–598. https://doi.org/10.1017/S0022029999003775.

[50] Saper RB, Rash R. Zinc: An essential micronutrient. American Family Physician. 2009;79:768–772.

[51] Klinger I, Rosenthal I. Public health and the safety of milk and milk products from sheep and goats. Revue Scientifique et Technique. 1997;16(2):482–488. https://doi.org/ 10.20506/rst.16.2.1034.

[52] Licata P, Di Bella G, Potortì AG, Lo Turco V, Salvo A, Dugo GM. Determination of trace elements in goat and ovine milk from Calabria (Italy) by ICP-AES. Food Additives and Contaminants. Part B: Surveillance. 2012;5(4):268–271. https://doi.org/10.1080/19393210.2012.705335.

[53] Bhoelan BS, Stevering CH, van der Boog AT, van der Heyden MA. Barium toxicity and the role of the potassium inward rectifier current. Clinical Toxicology (Philadelphia). 2014;52(6):584–593. https://doi.org/10.3109/15563650.2014.923903.

[54] Saribal D. ICP-MS analysis of trace element concentrations in cow's milk samples from supermarkets in Istanbul, Turkey. Biological Trace Elements Research. 2020;193:166–173. https://doi.org/10.1007/s12011-019-01708-4.

[55] Akhter P, Baloch NZ, Mohammad D, Orfi SD, Ahmad N. Assessment of strontium and calcium levels in Pakistani diet. Journal of Environmental Radioactivity. 2004;73(3):247–256. https://doi.org/10.1016/j.jenvrad.2003.08.011.

[56] Nabrzyski M, Gajewska R. Content of strontium, lithium and calcium in selected milk products and in some marine smoked fish. Nahrung. 2002;46(3):204–208. https://doi.org/10.1002/1521-3803(20020501)46:3<204::AID-FOOD204>3.0.CO;2-8.

[57] Panahifar A, Chapman LD, Weber L, Samadi N, Cooper DML. Biodistribution of strontium and barium in the developing and mature skeleton of rats. Journal of Bone and Mineral Metabolism. 2019;37(3):385–398. https://doi.org/10.1007/s00774-018-0936-x.

[58] Commission regulation (EC) no. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Union. 2006;49:5–24.

[59] Anderson RR. Comparison of trace elements in milk of four species. Journal of Dairy Science. 1992;75(11):3050–3055. https://doi.org/10.3168/jds.S0022-0302(92)78068-0.

[60] Manuelian CL, Albanell E, Rovai M, Caja G, Guitart R. Kinetics of lithium as a lithium chloride dose suitable for conditioned taste aversion in lactating goats and dry sheep. Journal of Animal Science. 2015;93(2):562–569. https://doi.org/10.2527/jas.2014-8223.

[61] Sundar S, Chakravarty J. Antimony toxicity. International Journal of Environmental Research and Public Health. 2010;7(12):4267–4277. https://doi.org/10.3390/ijerph7124267.

[62] McCallum RI. Occupational exposure to antimony compounds. Journal of Environmental Monitoring. 2005;7(12):1245–1250. https://doi.org/10.1039/b509118g.

[63] Lansdown AB. Critical observations on the neurotoxicity of silver. Critical Reviews in Toxicology. 2007;37(3):237–250. https://doi.org/10.1080/10408440601177665.

[64] Morishita Y, Yoshioka Y, Takimura Y, Shimizu Y, Namba Y, Nojiri N, Ishizaka T, Takao K, Yamashita F, Takuma K, Ago Y, Nagano K, Mukai Y, Kamada H, Tsunoda S, Saito S, Matsuda T, Hashida M, Miyakawa T, Higashisaka K, Tsutsumi Y. Distribution of silver nanoparticles to breast milk and their biological effects on breast-fed offspring mice. ACS Nano. 2016;10(9):8180–8191. https://doi.org/10.1021/acsnano.6b01782.

[65] Hadrup N, Lam HR. Oral toxicity of silver ions, silver nanoparticles and colloidal silver – a review. Regulatory Toxicology and Pharmacology. 2014;68(1):1–7. https://doi.org/10.1016/j.yrtph.2013.11.002.

[66] Goyer RA. Toxic and essential metal interactions. Annual Review of Nutrition. 1997;17:37-50. https://doi.org/10.1146/annurev.nutr.17.1.37.

[67] Chakraborty A, Basak S. Interaction with Al and Zn induces structure formation and aggregation in natively unfolded caseins. Journal of Photochemistry and Photobiology B. 2008;93(1):36–43. https://doi.org/10.1016/j.jphotobiol.2008.06.011.

[68] Metwally FM, Mazhar MS. Effect of aluminium on the levels of some essential elements in occupationally exposed workers. Archives of Industrial Hygiene and Toxicology. 2007;58:305–311. https://doi.org/10.2478/v10004-007-0021-7.

[69] John P, Kaore S, Singh R. Effects of calcium, strontium, and barium on isolated phrenic nerve-diaphragm preparation of rat and their interactions with diltiazem and nifedipine. Indian Journal of Physiology and Pharmacology. 2005;49(1):72–76.

[70] Mizushima S, Tsuchida K, Yamori Y. Preventive nutritional factors in epidemiology: Interaction between sodium and calcium. Clinical and Experimental Pharmacology and Physiology. 1999;26(7):573–575. https://doi.org/10.1046/j.1440-1681.1999.03083.x.

[71] Snodgrass GJ, Stimmler L, Went J, Abrams ME, Will EJ. Interrelations of plasma calcium, inorganic phosphate, magnesium, and protein over the first week of life. Archives of Disease in Childhood. 1973;48(4):279–285. https://doi.org/10.1136/adc.48.4.279.

[72] Yanagisawa T, Hashimoto H, Taira N. Interaction of potassium channel openers and blockers in canine atrial muscle. British Journal of Pharmacology. 1989;97(3):753–762. https://doi.org/10.1111/j.1476-5381.1989.tb12013.x.