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Analysis of 18 elements in Alpine goat milk in the first third of lactation

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Abstract

The research objective was to examine the influence of the first third of the lactation stage on 18 mineral elements in Alpine goat milk. The research was carried out on 20 goats of the French-Alpine breed, which were on average 5 years old and in the fourth lactation. The goats were monitored on the 30th and the 90th day of lactation. Their milk was analysed for chemical composition by the infrared spectroscopy. By means of inductively coupled plasma (ICP), a total of 18 minerals were analysed (Ca, P, K, Na, K, Mg, Fe, Zn, Cu, Se, Mn, Mo, Co, Cr, Ni, Cd, Pb, As and Hg). The period of milk sampling in the first third of lactation significantly influenced the changes in concentrations of Na, Se, Mo, Cr, Ni and As. Significantly higher concentrations of Na and As were determined in milk sampled on the 90th day, while lower concentrations of Se, Mo, Cr and Ni were determined in milk sampled on the 30th day of the first third of lactation. Analysis of the correlation coefficients between the investigated trace elements and the selected toxic elements in Alpine goat milk showed a significantly positive correlation between Ca:Mg, Ca:P, Ca:Co, Ca:Ni, Ca:Mo; Mg:P, Fe:As, Pb:Cd and P:Ni. In the first third of lactation, Alpine goat milk contained a very low concentration of heavy metals. The described changes indicate that Alpine goat milk is rich in essential elements, while the concentration of toxic elements is very low in the first third of lactation.

Keywords: Alpine goats; lactation; milk; elements

Introduction

Goat milk is nowadays in high demand, reaching the third place on the list of the most consumed types of milk (Klir et al., 2015; Guo et al., 2021). There are over one billion head of goats in the world, while its milk amounts to about 18.6 million tons, of which 15.14 % in Europe (2.8 million tons from over 15 million dairy goats) (FAO, 2024). The total number of goats in the Republic of Croatia was 65.227, while delivered quantities of goat milk were 3.556 tons in year 2022 (HAPIH, 2023). Contemporary research is focused on determining goat milk quality in dependence on not only goats' feeding regime, but also on other influencing factors, such as genotype/breed, lactation specifics (stage, order), etc. Milk and its products are rich sources of nutrients because of availability of almost all essential elements, especially for children (Ismail et al., 2017). Milk contains significant amounts of elements, especially essential macro elements (Ca, Mg, Na, K), trace elements (Zn, Co, Mo, Se, Cr and Ni), but also small amounts of toxic elements (heavy metals: Cd, Pb, As and Hg) (Llobet et al., 2003; Rey-Crespo et al., 2013; Fayet et al., 2013). In an animal organism, elements have numerous roles, which usually intertwine and significantly affect the growth and development, as well as the animal's production capability (Marquès et al., 2022, Sutlle, 2010). Toxic elements (Pb, Cd, As and Hg) do not have physiological functions in the body, and can cause numerous disorders even at low concentrations. Toxic elements in milk may origin from milk containers or contaminated water as well as through livestock feed and environment in which dairy animals are reared (Hussain et al., 2013; Briffa et al., 2020). In comparison to mammalian milk, goat milk has higher alkalinity, better digestibility, buffering capacity and therapeutic values (Park et al., 2007). Compared to cow milk, goat milk has higher contents of potassium, calcium, chloride, phosphorus, selenium, zinc and copper (Krstanović et al., 2010). Almašiova et al (2023) confirmed that goat milk is rich in essential elements, mainly Ca, Mg, K and Na, but contains toxic elements in very low amounts, often under the limit of detection. Many researches assessed the content of mineral elements in goat milk (Zhou et al., 2017; Antunović et al., 2018; Curró et al., 2019; Chen et al., 2020; Homayonibezi et al., 2020; Abba et al., 2021; Guo et al., 2021; Pan et al., 2023;). Also, many published studies focused on determination of the content of only several elements in the Alpine goat milk, and some researchers investigated the effects of lactation stage (Park and Chukwu et al., 1989; Voutsinas et al., 1990; Antunac et al., 2001; Antunović et al., 2012; Shuvarikov et al., 2021). However, there are no studies that investigated a broad scope of elements in milk of Alpine goats depending on the lactation stage. As lactation, especially in its first third, is a very demanding period for goats, it is expected that the quality of milk would be affected by it, so the authors investigated as many as 18 elements (macro- and micro elements and toxic metals) in Alpine goat milk to determine whether their content was influenced by the first third lactation stage.

Material and methods

The research was carried out by obeying legal provisions determined by the Animal Protection Act (Republic of Croatia Official Gazette No. 133 (2006), No. 37 (2013), and No. 125 (2013)), and approved by the Committee for Animal Welfare of the Faculty of Agrobiotechnical Sciences.

Animals and diets

The research was carried out on 20 French-Alpine goats kept at the Đurković family farm in the Croatian Osijek-Baranja County. On average, goats were 5 years old and all were in their fourth lactation. The investigated goats were selected from a herd of 50 goats, and all of the selected ones were healthy and in good physical condition. The goats were monitored on the 30th and 90th day of lactation (sampling period) during morning milking. They were kept in pens together with goat kids. Machine milking was done in a separate facility in the morning and evening, during feeding.

Before taking milk samples, goats were separated from the goat kids for 24 hours. Goats' diet was based on a feeding mixture with 16 % crude protein in the amount of 1.50 kg/day and alfalfa hay, which was offered to goats *ad libitum*. The ratio of voluminous and concentrated part of the diet was 60:40. Water was also available *ad libitum*.

Milk and feed analysis

Goat milk (morning milking) was sampled in two bottles (30 mL/bottle), which were cooled to 4 °C. One bottle of milk was used for analysis of chemical composition by infrared spectroscopy according to HRN ISO 9622:2017, in the MilkoScan FT 6000 analyser (Foss Electric, Hillerød, Denmark). The other bottle of milk sample was frozen at -80 °C. After defrosting, the sample was tested for concentrations of macro and micro elements (Ca, P, K, Na, K, Mg, Fe, Zn and Cu), values of which were expressed as mg kg^{-1}, and concentrations of Se, Mn, Mo, Co, Cr, Ni were presented as µg/kg. Content of selected toxic elements (Cd, Pb, As and Hg) was expressed also as µg/kg. Feed and goat milk samples were dissolved with 10 mL mixture of 5:1 HNO_3 and H_2O_2 at 180 °C over 60 min in a microwave oven (CEM Mars 6). Digestion of feed and milk samples of goats was carried out as described by Belete et al. (2014). Dilution of digest was carried out to 25 mL with deionized water. The concentrations of elements in goat milk, and in feed and water were determined by inductively coupled plasma mass spectrometer (ICP-MS, Agilent 7500a, Agilent Technologies Inc., Santa Clara, CA, USA) using continuous flow hydride generation technique. All samples were double analysed. According to Bosnak et al. (2004) digested samples for analyses of As were subjected to the pre-reduction step when 20 mL of sample was set in auto sampler tube (50 mL) and mixed with of KI and ascorbic acid solution (2 mL, 5 %). In mixture, 6 mL of HCl was

Table 1. Elements content in feed and water of Alpine goat in the first third of lactation

Parameters	Feed		Water	DIE, mg/feed mixture DM
	Feed mixture	Hay		
Ca, mg/kg DM	11094.50	5554.79	99.09	14811.16
P, mg/kg DM	4409.00	2657.00	0.0009	5886.02
K, mg/kg DM	8808.16	15230.05	2.76	11758.89
Na, mg/kg DM	2628.02	192.56	88.89	3508.41
Mg, mg/kg DM	1742.74	1811.27	26.52	2326.56
Fe, mg/kg DM	162.00	445.70	0.000003	216.27
Zn, mg/kg DM	61.73	20.99	0.03	82.41
Cu, mg/kg DM	9.29	5.62	0.03	12.40
Co, μg/kg DM	106.96	157.43	0.05	142.79
Mn, μg/kg DM	40260.00	12960.00	0.29	53747.1
Mo, μg/kg DM	474.20	1327.00	0.34	633.06
Se, μg/kg DM	98.27	299.00	0.18	131.19
Cr, μg/kg DM	1177.00	645.30	12.76	1571.30
Ni, μg/kg DM	1397.00	896.70	0.57	1865.00
Cd, μg/kg DM	54.77	29.72	< LD	73.12
Pb, μg/kg DM	372.50	632.40	< LD	497.29
As, μg/kg DM	164.20	140.90	3.01	219.21
Hg, μg/kg DM	< LD	1.12	0.006	-

DM - dry matter; LD - instrumental limit detection; DIE - daily intake of elements through feed mixture.

added and left at least 20 min. Deionized water was used to dilute sample until the 50 mL mark. Then samples were ready to run on ICP-MS. For the Se and Hg pre-reduction, a 20 mL of sample was placed in 125 mL beaker and 20 mL of HCl was added. This solution was transferred into 50 mL polypropylene autosampler tube and diluted with deionized water to 50 mL. The limit of detection (mg/kg) was as follows: Ca 0.01306; P 0.040048; K 0.401634; Na 0.047576; Mg 0.023112; Fe 0.00073; Zn 0.00143; Cu 0.00322; Co 0.0112; Mn 0.03967; Mo 0.04005; Se 1.31133; Cr 0.57387; Ni 0.28553; Cd 0.04344; Pb 0.01147; As 0.438, Hr 0,01216. The concentrations of elements in the feed and water of Alpine goats as well as daily intake of elements through feed mixture are presented in the Table 1.

Statistical analyses

Mean and standard deviation of chemical composition and elements in milk were processed by the MEANS procedure, while the influence of the sampling period on milk chemical composition and milk elements´ concentration was analysed by the GLM procedure and processed by the SAS 9.4®. Following model was used: $Yijk = \mu + s_i + e_{ij}$, where μ is overall mean, s_i is fixed effect of sampling period and e_{ij} is random error variation. Comparison between mean values of different groups were estimated by Tukey's test (p<0.05). Correlations among elements in goats´ milk were evaluated by Pearsons´ correlation with CORR procedure. The correlations were declared significant if p<0.05.

Results and discussion

In this research, no significant changes were found in most indicators of the basic chemical composition of Alpine goat milk sampled in the first third of lactation that could be related to the milk sampling period, except for a significant decrease in lactose concentrations in milk obtained during the second sampling compared to the first sampling (Fig. 1). Voutsinas et al. (1990), Antunac et al. (2001), Paskaš et al. (2023) and Bendelja Ljoljić et al. (2023) obtained similar results with Alpine goats, as well Antunović et al. (2018) in their research conducted on Croatian spotted goats.

Analysis of average concentrations of 18 elements (macro and micro elements and toxic elements) in Alpine goat milk showed greater standard deviations for less contained elements, which was expected (Table 2). When compared to our results, the research of Shuvarikov et al. (2021) conducted in Russia confirmed higher concentrations of Ca, Fe, Cu and Zn (145.3, 0.7589, 0.4372 and 5.0155 mg/kg, respectively) and lower concentrations of P, K and Mg (844.0, 1521.1 and 0.1251 mg/kg, respectively) in milk of Alpine goat. Chen et al. (2020) examined goat milk produced in China and obtained similar content of Cd (0.425 μg/kg), lower contents of Ca, K, Na, Mg, Mn and Cr (520, 1377, 253, 92.5, 0.156 mg/kg and 11.7 μg/kg, respectively), and higher contents of Cu, Zn, Se, As, Ni and Pb (0.208, 3.11 mg/kg, 1.08, 28.1, 4.27, Ni 38.3 and Pb 7.97 μg/kg, respectively) than the milk samples examined in our research. The research carried out in Austria on goat milk showed similar concentrations for Ca, Mg, Na and K (Mayer and Fiechter, 2012). As confirmed by our research, K (1954.38 mg/kg) was the most dominant macro element, followed by Ca, P and Na (1561.12, 1058 and 369.29 mg/kg, respectively). Chen et al. (2020) reported similar results. The observed concentrations of elements in goat milk indicate an adequate supply of these elements through food and water (Table 1). The concentration of Hg and Cd were the lowest in the present research, which was expected since this area is rural and without industry pollutants. Similar concluded Bilandžić et al. (2016).

The milk sampling period in the first third of the lactation was significantly influencing the changes in concentrations of Na, Se, Mo, Cr, Ni and As. Significantly higher concentrations of Na and As were determined in milk sampled on the 90th day and lower concentrations of Se, Mo, Cr and Ni were determined in milk sampled on the 30th day of the first third of lactation (Table 2). The concentration of essential elements in goat milk were within the recommended levels while the concentrations of toxic elements were under the allowed limits.

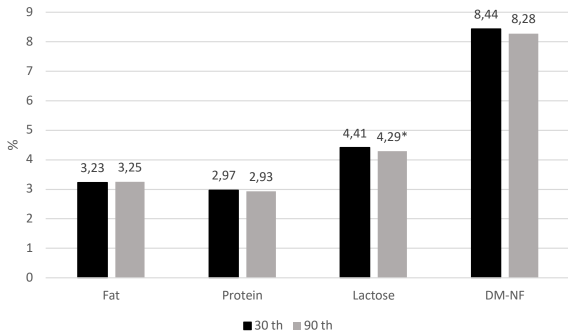

*Figure 1. Content (%) of fat proteins, lactose and dry matter non fat (DM-NF) in Alpine goat milk in the first third of lactation (*means significant difference, p<0.05)*

In Greece, Voutsinas et al. (1990) tested milk of Alpine goats in lactation (from the 8th to 35th week) to determine the increase in concentrations of Na, P and Mg and the decrease in concentration of K as the lactation progressed. They also reported the increase in the concentration of Ca, which was not determined in this research. Park and Chukwu (1989) reported that milk produced by the French-Alpine goats from 30th to 90th day of lactation did not exhibit significant changes in concentrations of Mn, Fe and Zn (0.3-0.3, 0.8-0.7 and 5.1-5.2 mg/kg, respectively), yet the concentration of Cu (0.9-1.2 mg/kg) was significantly increased. In the research on milk of Alpine goats raised in Croatia under ecological conditions, Antunović et al. (2012) did not prove significant changes in concentration of heavy metals and reported that their average values were below allowed limits for heavy metal content in milk. In another research by Antunović et al. (2018) carried out on Croatian spotted goats, it was determined that concentrations of Ca, Mg, P, Zn and Mo significantly increased as lactation progressed. The concentrations of Na, Cu, Fe and Pb also increased, and the concentration of K decreased over lactation, while concentrations of Mn and Ni did not vary in dependence on lactation stage. According to Commission Regulation (EU) 2023/915 (2006) the highest allowed concentration of Pb in raw milk is 0.02 mg/kg. This pointed out the very low concentrations of Pb determined in this research and the preservation of the land areas from which the feed for the goats is prepared. The presence of Pb in milk could be due to different factors (fodder contamination, climatic factors, used pesticide

Table 2. Effect of lactation stage on the concentration of 18 elements (Mean±SD) in Alpine goat milk during the first third of lactation

Parameter, mg/kg	Sampling period		The first third of lactation	P-value
	Sampling point I (30th day)	Sampling point II (90th day)		
Ca	1574.19±178.47	1547.39±199.96	1561.12±187.36	0.653
Mg	138.15±24.53	149.39±20.96	143.63±23.28	0.124
K	1965.25±153.31	1942.97±204.49	1954.38±178.16	0.694
Na	323.74±42.54	417.12±160.61	369.29±124.06	0.014
Cu	0.10±0.03	0.10±0.05	0.10±0.04	0.733
Fe	0.26±0.06	0.37±0.28	0.31±0.21	0.079
Zn	2.97±0.52	2.76±0.54	2.86±0.54	0.213
P	1052.15±97.63	1063.25±118.88	1058±107.29	0.745
Mn, µg/kg	27.23±8.86	28.02±11.61	27.62±10.17	0.808
Se, µg/kg	22.30±20.10	20.13±3.00	21.24±2.77	0.011
Mo, µg/kg	15.44±4.47	12.58±4.35	14.04±4.59	0.045
Cr, µg/kg	59.88±10.17	50.88±8.95	55.49±10.51	0.005
Co, µg/kg	0.64±0.10	0.61±0.11	0.62±0.10	0.365
Ni, µg/kg	5.46±0.65	4.91±0.72	5.19±0.74	0.014
As, µg/kg	1.11±0.29	1.60±0.41	1.35±0.43	<0.001
Cd, µg/kg	0.50±0.37	0.33±0.25	0.42±0.32	0.100
Hg, µg/kg	0.06±0.12	0.06±0.05	0.06±0.09	0.797
Pb, µg/kg	1.75±1.57	3.27±3.24	2.49±2.20	0.051

SD - standard deviation

compounds, various industrial activities, contaminated water irrigation systems and other (Licata et al., 2004; Antunović et al., 2023). Bilandžić et al. (2016) performed a research on goat milk in Croatia from rural areas during 5 years and observed Pb concentrations from 9.33 to 60.0 µg/kg with average values 15.1 µg/kg. Hejtmankova et al. (2002) determined an increase in Mg and Fe concentrations during lactation for goat milk produced in Czech Republic. Güler (2007) explained that higher concentrations of Mg in goat milk might be caused by sudden physiological changes, metabolic processes in mammary gland, changes in diet, lactation stage, environmental temperature, and water intake. Kezdzierska-Matysek et al. (2015) found significant differences as affected by lactation stage in concentrations of K and Na, while a significant Ca and Mg concentrations increased, and opposite trend was determined for concentrations of Zn, Fe and Cu in goats' milk in Poland. Michlova et al. (2016) determined that the content of some elements (Ca, Mg, K, Na, Zn and Cu) in goat milk collected during lactation period from different goat breeds kept at various farms in Czech Republic were very variable. Garba et al. (2018) pointed out that factors such as period of lactation and the amount of feed affected the increase in the levels of metals in cow milk. In goat milk obtained from autochthonous breeds and from the Saanen in Italy, Curró et al. (2019) also determined a significant increase in concentrations of Na in the 4^{th} and 8^{th} week of lactation when compared to the 24^{th} week of lactation. The increase in concentration of Mg and the decrease in Zn in milk of the Pantja goat in India was reported by Chauhan et al. (2019).

Strzalkowska et al. (2008) carried out a research on Polish white improved goats and determined a significant increase in Na and Mg concentration of milk at the beginning of the lactation in comparison to the end lactation (10 months). The same authors determined opposite changes for Zn milk concentration during lactation. The observed changes during lactation were most probably caused by an excess intake of Na if the animals had a free access to salt lick (NRC, 2007). Stocco et al. (2019) determined a significant increase in Mg and Fe concentrations in Italian cow milk during lactation, as well as lower Zn concentration during the first third of lactation, which was in accordance with the results of the present research.

The concentrations of Mg, K, and Na in goat milk in the study carried out in Brazil decreased linearly ($p < 0.001$) throughout the 56 days of lactation (Filho et al., 2024). The reason for absence of significant changes in mineral concentrations in milk of Alpine goats in the present research could be related to effect of different lactation stage when production and chemical composition of milk changed which is also determined in previous research. Similarly concluded Strzalkowska et al. (2008). Pan et al. (2023) determined that concentrations of Ca, Zn, Cr, Cu, Mn and Fe in goat milk were mainly distributed in the casein fraction in comparison to other fractions. According to very low concentration of toxic elements observed, goat milk can be considered as safe and beneficial for human health.

Analysis of the correlation coefficients between the investigated elements in Alpine goat milk, showed that there was significantly positive correlation between Ca:Mg, Ca:P, Ca:Co, Ca:Ni, Ca:Mo; Mg:P, Fe:As, Pb:Cd and P:Ni (Table 3). Numerous significant correlations were estimated between various parameters in goats' milk during lactation, which were expected, because of their metabolic interrelations as well as differences in metabolic background of the animals. Similar concluded Singh et al. (2015) in Beetal goat breed in India. In Greece, Voutsinas et al. (1990) tested Alpine goat milk to determine a strong positive correlations between Ca:P (0.947), Ca:Mg (0.710), and Mg:P (0.630), as well as a high negative correlation between Na:K (0.789), which was of the same direction but without significance in this research. In milk of goats raised in China, Chen et al. (2020) determined significant correlations between Cd:Pb (r=0.723), Cd:Cr (r=0.774) and Cd:As (r= 0666) and explained that they were probably related to environmental factors. In the research conducted in Poland, Kędzierska-Matysek et al. (2015) also determined a strong positive correlation between Ca:Mg (0.65***) in goat milk.

Table 3. Correlation coefficients of 18 elements in Alpine goat milk during the first third of lactation

	Ca	Mg	K	Na	Cu	Fe	Zn	P	Cr	Mn	Co	Ni	As	Se	Mo	Cd	Hg	Pb
Ca	1.00																	
Mg	0.69 <0.001	1.00																
K	-0.13 0.421	-0.05 0.77	1.00															
Na	0.22 0.166	0.27 0.091	-0.31 0.048	1.00														
Cu	0.33 0.036	0.420 0.006	-0.01 0.934	-0.04 0.799	1.00													
Fe	0.03 0.857	0.06 0.687	-0.03 0.859	0.01 0.927	0.07 0.657	1.00												
Zn	-0.06 0.720	0.06 0.697	0.02 0.920	-0.05 0.740	0.14 0.371	-0.03 0.869	1.00											
P	0.73 <0.001	0.66 <0.001	0.29 0.067	0.26 0.104	0.34 0.031	0.08 0.616	0.18 0.272	1.00										
Cr	0.27 0.094	0.24 0.131	-0.13 0.405	-0.25 0.121	0.27 0.091	-0.08 0.623	0.36 0.019	0.21 0.194	1.00									
Mn	0.24 0.137	0.18 0.269	0.15 0.364	0.22 0.167	0.09 0.570	0.002 0.989	0.05 0.779	0.39 0.012	0.08 0.637	1.00								
Co	0.50 0.001	0.40 0.010	0.05 0.761	0.10 0.545	0.18 0.250	0.15 0.354	-0.07 0.674	0.34 0.028	0.27 0.087	0.21 0.186	1.00							
Ni	0.764 <0.001	0.45 0.003	-0.16 0.328	-0.09 0.566	0.16 0.328	0.07 0.667	0.10 0.519	0.54 0.0003	0.44 0.004	0.07 0.655	0.47 0.00	1.00						
As	0.23 0.147	0.34 0.028	0.09 0.568	0.20 0.201	0.03 0.849	0.65 <0.001	-0.32 0.044	0.310 0.049	-0.23 0.155	0.24 0.125	0.27 0.083	0.01 0.908	1.00					
Se	0.42 0.006	0.06 0.722	0.05 0.732	0.26 0.094	0.13 0.413	-0.29 0.062	-0.09 0.594	0.33 0.034	0.20 0.210	0.25 0.116	0.16 0.322	0.35 0.027	-0.12 0.451	1.00				
Mo	0.57 <0.001	0.22 0.158	-0.04 0.811	0.14 0.383	0.14 0.374	-0.12 0.471	-0.3 0.027	0.40 0.009	0.15 0.353	0.28 0.072	0.32 0.043	0.54 0.0003	0.04 0.813	0.47 0.002	1.00			
Cd	-0.15 0.365	0.11 0.501	-0.02 0.895	-0.46 0.003	0.42 0.008	-0.04 0.816	0.34 0.032	-0.13 0.431	0.22 0.181	-0.23 0.153	0.04 0.831	0.04 0.816	-0.10 0.56	-0.30 0.067	-0.29 0.070	1.00		
Hg	0.26 0.114	0.45 0.004	0.14 0.396	-0.08 0.654	0.23 0.167	0.177 0.288	-0.10 0.566	0.29 0.082	-0.21 0.215	0.19 0.261	0.15 0.353	0.04 0.805	0.34 0.034	-0.24 0.151	0.24 0.151	0.18 0.288	1.00	
Pb	-0.17 0.301	0.21 0.190	0.06 0.718	-0.27 0.091	0.45 0.004	0.05 0.778	0.04 0.814	-0.14 0.396	-0.27 0.084	-0.29 0.067	-0.26 0.097	-0.24 0.127	0.05 0.766	-0.47 0.002	-0.34 0.029	0.59 <0.001	0.32 0.047	1.00

Conclusion

According to the obtained research results, it can be concluded that the milk sampling period significantly influenced the content of lactose and the concentrations of Na, Se, Mo, Cr, Ni and As in Alpine goat milk in the first third of lactation. Milk of Alpine goats sampled in the first third of lactation had a very low concentration of heavy metals and significantly positive correlation between Ca:Mg, Ca:P, Ca:Co, Ca:Ni, Ca:Mo; Mg:P, Fe:As, Pb:Cd and P:Ni. The observed changes indicate that Alpine goat milk is rich in essential elements, while the concentration of toxic elements is very low in the first third of lactation.

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Analiza 18 elemenata u mlijeku alpina koza u prvoj trećini laktacije

Sažetak

Cilj ovoga rada bio je utvrditi utjecaj stadija laktacije u prvoj trećini laktacije na 18 elemenata sadržanih u mlijeku alpina koza. Istraživanje je provedeno na 20 koza pasmine francuska alpina, prosječne dobi 5 godina i u četvrtoj laktaciji, koje su praćene 30. i 90. dana laktacije. U uzorcima mlijeka je određen osnovni kemijski sastav infracrvenom spektrofotometrijom te koncentracija 18 elemenata (Ca, P, K, Na, K, Mg, Fe, Zn, Cu, Se, Mn, Mo, Co, Cr, Ni, Cd, Pb, As i Hg) primjenom induktivno spregnute plazme (ICP). Vrijeme uzorkovanja mlijeka u prvoj trećini laktacije značajno je utjecalo na promjene koncentracije Na, Se, Mo, Cr, Ni i As. Utvrđene su značajno više koncentracije Na i As u mlijeku 90. dana uzrokovanja te niže Se, Mo, Cr i Ni 30. dana uzorkovanja tijekom prve trećine laktacije. Analizom koeficijenata korelacije između istraživanih elemenata u tragovima i određenih toksičnih elemenata u mlijeku alpina koza utvrđena je značajno pozitivna korelacija između Ca:Mg, Ca:P, Ca:Co, Ca:Ni, Ca:Mo; Mg:P, Fe:As, Pb:Cd i P:Ni. Utvrđena je vrlo niska koncentracija teških metala u mlijeku alpina koza u prvoj trećini laktacije. Navedene promjene ukazuju da je mlijeko Alpina koza bogat izvor esencijalnih elemenata, dok je koncentracija toksičnih elemenata bila vrlo niska u prvoj trećini laktacije.

Ključne riječi: alpina koze; laktacija; mlijeko; elementi

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