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Vitamin and mineral composition of craft goat milk butter during refrigerated storage

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The expansion of the range of dairy products with health-promoting properties on the world market is largely ensured by the development of craft production, focused on naturalness, minimal processing and compliance with food safety requirements. Goat milk butter attracts particular attention, which, due to its functional properties and growing popularity among consumers, requires a thorough assessment of its vitamin and mineral value. The content of retinol, tocopherol and riboflavin, as well as macro-, microelements and heavy metals, was determined in the butter on the 1st, 10th and 20th days. The content of vitamins in the butter was determined using fluorometry and photocolorimetry, and mineral components - by inductively coupled plasma optical emission spectrometry. When storing goat milk butter for 20 days at a temperature of 4 ± 1 ºC, no changes in the concentration of retinol and riboflavin were detected, but a decrease in the content of tocopherol was recorded on the 10th day by 10.23% and on the 20th day by 14.42%. The mineral composition of goat milk butter did not change during the entire storage period. With a decrease in the concentration of macroelements in the butter, they were in the following order: P < Na < K < Ca < Mg. The level of microelements in the butter was distributed as follows: Zn < Fe < Cu < Mn = Mo < Co < Se. Among the heavy metals in the butter, aluminium was characterised by the highest concentration, while arsenic and antimony were present below the limit of detection, allowing them to be arranged in the following order: Al < Pb = Ni < Cr < Hg < Cd < As = Sb. The highest estimated daily intake into the human body with the butter was found for iron and aluminium, and the minimum for molybdenum, cobalt and manganese. According to the target hazard quotient (THQ), heavy metals that can potentially enter the body of a consumer with the butter can be placed in the following order: Hg < Pb < Cd = Cr < Al < Ni < Zn < Cu = Fe < Mn < Mo < Co. For all heavy metals, THQ did not exceed 1 during the entire storage period of the butter. Taking into account the maximum human consumption of butter in the amount of 30 g per day, there is no risk of heavy metal poisoning. In terms of the content of vitamins, macro-, microelements and heavy metals, butter from goat milk can be one of the criteria for geographical and ecological authenticity of dairy products.

Keywords: butter; unpasteurised cream; retinol; tocopherol; riboflavin; microelements; heavy metals.

Introduction

Milk and dairy products are among the most widely consumed food products on the market due to their naturalness and dietary properties (Chudy et al., 2022; Bal-Prylypko et al., 2023; Wilmot et al., 2025). Among them, butter occupies an important place as a product with functional properties and is a concentrate of essential saturated and unsaturated fatty acids, triglycerides, phospholipids and vitamins (Lapčíková et al., 2022; Gündoğdu & Beşer, 2024). Butter is a traditional dairy product in many countries around the world and consists mainly of fat (the proportion of which reaches 80%) and about 16% moisture. (Pădureţ, 2021). However, the attitude of nutritionists to this product is quite controversial. It is generally accepted that milk fat is a risk factor for human health due to the high level of saturated and insufficient levels of polyunsaturated fats. However, products made from goat milk, including butter, are considered health-promoting, which has increased demand for them in recent years in many developed countries of the world. Moreover, this trend is also due to the growing interest in delicatessen and functional food products produced in conditions as close to natural as possible (Timlin et al., 2024; Davydovych et al., 2026c).

Despite the fact that the main share of goat milk in both industrial and craft production is intended for the production of hard, soft and brine cheeses (Sadvari et al., 2024a, 2024b), recently more attention has been paid to the production of butter. Butter from goat milk is a very specific and rather rare product, the niche of which in the dairy market is gradually increasing. It differs significantly from butter produced from cow's milk, as it is characterised by a whiter colour, a specific smell and taste, and a higher fat content. It is also known that butter from goat's milk contains a higher amount of vitamins, has more pronounced antioxidant, anti-allergic, and immunostimulating properties in the human body (Ermolaev & Ruban, 2025).

Many studies have focused on the quality, safety, and functional properties of butter from pasteurised or fermented cream (Lee, 2020). There is increasing attention to improving the temperature regime of raw materials for butter production, as high temperature processing significantly reduces their antioxidant properties (Tripaldi et al., 2021) and creates conditions for the oxidation of biologically active compounds, in particular vitamins.

Nowadays, various techniques are used to provide functional features to dairy products, including butter, for example, grazing ruminants on natural pastures (Magan et al., 2021), as well as enrichment of milk and cream with vitamins, vegetable and fruit extracts, antioxidants and probiotics (Gündoğdu et al., 2020; Vasheka et al., 2021; Jetpisbayeva et al., 2025). It is believed that butter acquires special properties when lactic acid bacteria, in particular *Lactobacillus helveticus*, *L. paracasei*, *Lactococcus lactis* subsp. *lactis* biovar. *Diacetylactis* or *Leuconostoc mesenteroides* subsp. *cremoris*, are used in its fermentation (Naurzbayeva et al., 2023). These studies showed that butter with probiotic additives had better sensory qualities, which were due to the presence of 61 types of volatile substances, such as esters, aldehydes, ketones, alcohols and acids. In addition, the addition of probiotics or lactic acid cultures to butter not only had a positive effect on its beneficial properties for the human body, but also increased its shelf life. It should be noted that this approach is suitable for the production of butter from pasteurised cream (Silva et al., 2023), but this does not eliminate the problem of low survival of probiotic microorganisms during application and storage of butter. If we consider that the loss of beneficial strains of lactic acid bacteria during digestion in the human body is about 2 log10 CFU/g, then this significantly reduces the probiotic properties of the finished product (da Silva et al., 2021). In other studies, probiotic microorganisms were included directly in the milk matrix, but this led to an undesirable effect on the organoleptic properties of the product due to a decrease in the viability of probiotic microorganisms during storage (Ferreira et al., 2020).

One of the promising ways to enrich butter with beneficial lactic acid bacteria is to use unpasteurised cream from goat milk, which is often practised in craft production. The main disadvantage of this method is the increased risk of pathogenic and conditionally pathogenic microorganisms, which are causative agents of foodborne toxicoinfections, entering and multiplying in the finished product. At the same time, the use of unpasteurised cream in butter production offers significant advantages, notably by enabling the manufacture of distinctive products containing viable beneficial lactic acid bacteria in quantities and proportions that are optimally suited to the human digestive system. This determines the ecological and geographical authenticity of such dairy products (Lei et al., 2025), and also allows the development of the economy of small farms and small communities through gastronomic tourism (Ferreira et al., 2020).

Analysis of the literature shows that butter from goat milk is rarely mentioned in the literature, and butter from unpasteurised goat milk is rarely mentioned at all, despite the significant prevalence of dairy products in the Mediterranean countries, the Middle East and Africa. Information on the chemical composition and sensory characteristics of butter from unpasteurised goat milk during refrigerated storage is critically limited (Silva et al., 2023).

Therefore, the purpose of the research was to determine the effect of the shelf life of butter from unpasteurised goat milk cream on the vitamin and mineral composition.

Materials and methods

For the production of craft butter, goat milk was used, produced in the conditions of the Eco Farm "Zhuravka" (Kyiv region, Ukraine) in November 2025. The butter was made from unpasteurised cream, which is obtained by separating milk heated to a temperature of 40 ºC. Separation was carried out using a Motor Sich SCM 100-18 separator (JSC "MOTOR Sich", Zaporizhzhia, Ukraine). The obtained cream was left to ripen in a refrigerator at a temperature of 4 ± 1 ºC for 6 days until a solid consistency. Filtered purified drinking water was added to the ripened cream in a ratio of 1:1 and whipped at a temperature of 15–17 ºC using an electric butter churn for butter Motor Sich MBE-6 (JSC "MOTOR Sich", Zaporizhzhia, Ukraine). After whipping the butter, the butter churn was drained, and the butter was washed with ice-cold purified drinking water three times. A total of 15 kg of butter was produced, from which briquettes weighing 200 g were formed, packed in parchment paper for butter and stored in a refrigerator at a temperature of 4 ± 1 ºC. To analyse the vitamin and mineral composition, 5 samples of butter in briquettes were taken on the 1st, 10th, and 20th day of storage in triplicate.

The content of vitamins and mineral elements in goat milk butter was tested at the testing centre of the State Research Institute for Laboratory Diagnostics and Veterinary and Sanitary Expertise, Kyiv, Ukraine, which is accredited by the National Accreditation Agency of Ukraine according to the requirements of DSTU EN ISO/IEC 17025:201.

The determination of the retinol content in the butter was carried out by the phototocolorimetric method using a photoelectric photometer KFK-3-01 (AO "Zomz", Sergiev-Posad, Russia). The riboflavin content in the butter was investigated by the fluorometric method using the Fluorat-02-2M analyser (FNVF AP "Lumex", St. Petersburg, Russia). The tocopherol level in the butter samples was determined by the photocolorimetric method using a photoelectric photometer KFK-3-01 (AO "Zomz", Sergiev-Posad, "Zomz", Sergiev-Posad, Russia). Reagents for chemical analysis were manufactured by Thermo Fisher Scientific (USA).

To determine the mineral composition of the butter, the sample was prepared using a closed-type Microwave mineraliser. Laboratory Systems, Milestone (Italy, Bergamo, 2015). The study of the content of calcium, phosphorus, sodium, potassium, magnesium, copper, zinc, iron, manganese, molybdenum, cobalt, lead, cadmium, chromium, aluminium, nickel, selenium, antimony and arsenic in the samples was carried out on an ICP optical emission spectrometer (ICP-OES) PlasmaQuant PQ 9000 Analytik Jiena (Germany, Jena, 2015). Determination of mercury content in the butter samples was carried out using a Milestine DMA 80 mercury analyser (Italy, Milan, 2018). A Liebherr refrigerator and freezer (Switzerland, Bühl, 2015) was used to store the samples. The detection limit was for calcium – 5.0 µg/kg, phosphorus – 3.0 µg/kg, sodium – 1.0 µg/kg, potassium – 5.0 µg/kg, magnesium – 5.0 µg/kg, copper – 2.0 µg/kg, zinc – 5.0 µg/kg, iron – 5.0 µg/kg, manganese – 2.0 µg/kg, molybdenum – 0.1 µg/kg, cobalt – 0.01 µg/kg, lead – 1.0 µg/kg, cadmium – 0.1 µg/kg, chromium – 0.1 µg/kg, aluminum – 2.0 µg/kg, nickel – 1.0 µg/kg, selenium – 1.0 µg/kg, antimony – 1.0 µg/kg and arsenic – 1.0 µg/kg. Analytical signals were processed automatically using the spectrometer software, using calibration dependencies taking into account background correction, and if necessary, the mutual influence of the studied elements. To control the sensitivity fluctuations of the ICP-OES analysis, an internal standard sample with an indium content of 20 µg/L of solution (Roti® Star) was used. The determination of mercury content in the butter samples was carried out by a direct method according to ISO 11212 – 2:1997 (E) Part 2 Determination of mercury content by atomic absorption. The detection limit for mercury in the samples was 0.01 µg/kg.

To assess the risk of heavy metals for consumers, the estimated daily intake (EDI) of the most dangerous elements exhibiting heavy metal characteristics was used, according to the formula (Ribeiro Sant'Ana et al., 2021):

$$EDI = Cm \times Wf / BW \text{ (mg/kg/day)},$$

where Cm – metal content in butter, mg/kg (the average mineral content in butter over a storage period of 20 days was used for calculation); Wf – average daily consumption of butter per person (taken as maximum, 30 g); BW – the body weight of an adult (70 kg).

Using EDI, the target hazard quotient (THQ) was calculated using the following formula:

$$THQ = EDI / RFDo,$$

where RFDo – the human reference oral dose of each element that indicates a safe limit for health effects.

A THQ value of < 1 is considered to indicate an acceptable level of exposure with minimal risk to human health, whereas a value ≥ 1 suggests potential adverse effects (Rocha et al., 2023).

Statistical analysis of the results of the analysis of the vitamin and mineral composition of butter from unpasteurised goat milk cream was performed using a one-way analysis of variance (ANOVA). The content of vitamins, macro-, microelements and heavy metals in butter was compared between storage periods. The data in the tables are presented as x ± SD (mean ± standard deviation). The difference between the options was considered significant at $P < 0.05$ using the Tukey test.

Results

Analysis of butter from unpasteurised goat milk cream showed that the storage period did not affect the content of retinol and riboflavin in it (Table 1). At the same time, the concentration of tocopherol decreased with increasing storage period of butter, in particular, on the 10th day by 10.23% and on the 20th day by 14.42% compared to the data on the 1st day of storage.

The content of macronutrients in the goat milk butter did not depend on its storage period, and their levels were in the following order: P < Na < K < Ca < Mg (Table 2). The ratio of calcium to phosphorus during the storage period of the butter varied from 1:2.6 to 1:3.2.

As for microelements in butter, the storage period did not affect their content, and the fluctuations that were noted were in a small range and did not have a significant difference. By content in butter, microelements were placed in the following order: Zn < Fe < Cu < Mn = Mo < Co < Se.

Table 1
Vitamin content in goat milk butter during storage (x ± SD, mg/kg)

Vitamin name	Shelf life, days		
	1	10	20
Retinol	11.20 ± 0.47[a]	10.73 ± 0.59[a]	10.86 ± 0.24[a]
Tocopherol	2.15 ± 0.11[a]	1.93 ± 0.12[b]	1.84 ± 0.05[b]
Riboflavin	3.43 ± 0.24[a]	3.51 ± 0.26[a]	3.69 ± 0.17[a]

Note: different superscript letters indicate a significant difference between values in a row of the table ($P < 0.05$) using the Tukey test.

Table 2
The content of macro- and microelements
in butter from goat milk during storage (x ± SD, n = 5)

Indicator	Shelf life, days		
	1	10	20
	Macronutrients		
Na, mg/kg	1.04 ± 0.07	1.02 ± 0.16	0.95 ± 0.13
Ca, mg/kg	0.53 ± 0.03	0.59 ± 0.09	0.57 ± 0.07
P, mg/kg	1.61 ± 0.13	1.53 ± 0.21	1.52 ± 0.11
K, mg/kg	0.81 ± 0.08	0.75 ± 0.09	0.76 ± 0.06
Mg, mg/kg	0.083 ± 0.006	0.081 ± 0.005	0.087 ± 0.007
	Micronutrients		
Zn, mg/kg	3.24 ± 0.39	3.06 ± 0.13	3.12 ± 0.28
Fe, μg/kg	14.96 ± 2.30	13.80 ± 1.47	14.01 ± 2.57
Mn, μg/kg	0.047 ± 0.004	0.041 ± 0.008	0.048 ± 0.009
Cu, μg/kg	0.75 ± 0.09	0.69 ± 0.06	0.71 ± 0.08
Mo, μg/kg	0.055 ± 0.011	0.048 ± 0.008	0.046 ± 0.009
Co, μg/kg	0.022 ± 0.006	0.023 ± 0.005	0.021 ± 0.004
Se, μg/kg	< 1.00	< 1.00	< 1.00

Note: no significant changes in the content of macro- and microelements in butter were detected during the storage period.

The content of heavy metals in the butter from goat milk did not change significantly during the entire storage period (Table 3). Of all the elements studied, aluminium occupied the largest share, and the content of arsenic and antimony did not exceed the detection limit. Thus, heavy metals in terms of quantity in the butter can be placed in the following order: Al < Pb = Ni < Cr < Hg < CD < As = Sb.

Table 3
Heavy metal content in goat milk butter
during storage (μg/kg, x ± SD, n = 5)

Indicator	Shelf life, days		
	1	10	20
Al	13.65 ± 1.29	13.42 ± 1.12	12.52 ± 1.91
Pb	1.78 ± 0.32	1.83 ± 0.28	1.70 ± 0.14
Ni	1.49 ± 0.23	1.36 ± 0.16	1.31 ± 0.15
Cr	0.94 ± 0.08	1.01 ± 0.08	0.99 ± 0.06
Cd	0.19 ± 0.03	0.18 ± 0.04	0.20 ± 0.05
Hg	0.32 ± 0.04	0.28 ± 0.07	0.29 ± 0.05
As	< 1.00	< 1.00	< 1.00
Sb	< 1.00	< 1.00	< 1.00

Note: no significant changes in heavy metal content in butter were detected during storage.

The risk assessment of heavy metal toxicity when consuming butter from goat milk shows that the highest estimated daily intake (EDI) in the composition of the butter was intake of iron and aluminium, with slightly lower intakes of zinc, lead, nickel, chromium, copper, mercury and cadmium, and the lowest intakes of molybdenum, cobalt and manganese (Table 4). Considering that the average consumption of butter does not exceed 30 g per day, the intake of minerals related to heavy metals into the consumer's body is insignificant and cannot cause concern.

According to the hazard coefficient, heavy metals in butter can be placed in the following order: Hg < Pb < Cd = Cr < Al < Ni < Zn < Cu = Fe < Mn < Mo < Co. Calculation of the target hazard quotient (THQ) for elements found in goat milk butter that are capable of exhibiting heavy metal properties in the body of consumers showed that all metals, without exception, not only did not exceed 1, but also did not approach this mark during the entire storage period.

Table 4
Risk assessment of craft butter from unpasteurised goat milk
cream for consumer health based on heavy metal content

Element	RFD_o	Parameter	
		EDI, lg	THQ
Zn	0.3	-5.87	0.000004
Fe	0.7	-5.22	0.000008
Mn	0.14	-7.79	0.0000001
Cu	0.04	-6.51	0.000008
Mo	5.0	-7.73	0.000000004
Co	30.0	-8.01	0.0000000003
Al	0.4	-5.25	0.000014
Pb	0.004	-6.11	0.0002
Ni	0.02	-6.22	0.00003
Cr	0.003	-6.38	0.00014
Cd	0.001	-7.11	0.0001
Hg	0.0001	-6.89	0.0013

Note: EDI was calculated in lg mg/kg body weight per day; RFDo – the human reference oral dose of each element that indicates a safe limit for health effects; THQ – target hazard quotient.

Discussion

Fat-soluble vitamins contained in milk are able to concentrate in the fat during churning of butter, and they not only give it biological activity, but also provide antioxidant function. Lipophilic vitamins, which are most often monitored in butter, include retinol and tocopherol. These compounds are present in the globules of milk fat and are able to quench singlet oxygen, preventing the oxidation of a significant number of essential components. This is especially important for fats that contain a significant amount of polyunsaturated fatty acids, which are capable of destruction during storage, in particular butter from goat milk (Khan et al., 2019). In addition to fat-soluble vitamins, goat milk butter also contains B vitamins, especially riboflavin. Its concentration is quite significant despite the fact that the butter is washed with water, which implies the loss of part of this vitamin with the buttermilk and washing water (Hrubša et al., 2022). As the results of the study showed, retinol and riboflavin were not destroyed during 20 days of storage in a refrigerated form, and tocopherol was the most sensitive to destruction, the concentration of which was characterised by an inversely proportional dependence on the storage period of goat milk butter.

Storage of butter made from unpasteurised cream can cause changes and changes in the direction of chemical reactions due to the presence of indigenous strains of microorganisms, in particular lactic acid bacteria, fungi and yeasts, found in raw milk. The enzymatic activity of microorganisms in unpasteurised cream can affect the shelf life and, therefore, the quality and safety of the butter (Gaba et al., 2023; Lalwani et al., 2024). Since goat milk butter is a dietary product, it is important to determine the criteria for suitability, biological value and safety for consumers during its storage. The shelf life of the product indicates the absence of physical and organoleptic inconsistencies in it, and most importantly, the preservation of the original content of nutrients and biologically active substances, then such a product is suitable for consumption (Rauh & Xiao, 2022), in particular, in terms of the content of individual fat-soluble and water-soluble vitamins and mineral components.

During storage, numerous changes in the nutritional and technological properties of milk and dairy products can occur, with changes in nutritional values including, for example, protein degradation, vitamin loss and changes in mineral balance (Rauh & Xiao, 2022), the latter mainly caused by a decrease in pH during storage (Anema, 2017). Vitamin losses are believed to depend on the mode and duration of heat treatment of dairy products, as well as on storage conditions (Kilic-Akyilmaz et al., 2022). The influence of technological processes and storage conditions on the content of vitamins A and E in butter during storage at a temperature of 5 ± 2 °C for 90 days was revealed. In this study, the loss of vitamins A and E was found to be 23% and 17%, respectively, at the end of the storage period. One of the reasons for the oxidation of these vitamins is considered to be the increase in the peroxide and acid numbers of butter during storage. Moreover, this study showed the relationship between the content of vitamins A and E and the peroxide number of fat ($R^2 = 0.9184$ and $R^2 = 0.8470$, respectively), as well as the content of vitamins A and E and the acid number of fat ($R^2 = 0.9367$ and $R^2 = 0.8934$, respectively) (Öktürk et al., 2001). Another experiment, when studying butter from cow, sheep and goat milk, showed a decrease in vitamin D after storage for 90 days at 4 °C. A and β-carotene against the background of increasing oxidation rates (Çakmakçı & Tahmas Kahyaoğlu, 2018).

Another study found conflicting results regarding the content of vitamins B_1 and E in butter (Kilic-Akyilmaz et al., 2022), which indicates the need to clarify the relationships between various technological processes and storage conditions of finished dairy products with a high fat content. Of particular importance is the temperature treatment of milk cream, which in industrial conditions may include high-temperature short-term pasteurisation, processing with an extended shelf life and ultra-high temperature processing. This caused vitamin losses in the range of 1–22%. At the same time, more pronounced vitamin losses were observed with more intensive heat treatment and longer storage. Different sensitivity of vitamins to the temperature factor was revealed, in particular, the content of vitamin B_{12} was characterised by a greater tendency to decay than vitamins B_1, B_2 and E. The shelf life of cream was characterised by a higher impact on the stability of vitamins than heat treatment. During long-term storage, a significant impact on the physical stability and colour changes of milk and cream was observed (Lalwani et al., 2024).

As for the goat milk butter in our study, it was made from unpasteurised cream, which excludes any high-temperature treatment of both the raw material and the product itself during storage. Therefore, the decrease in tocopherol content that we observed could be due to fat acidification, which is considered a key factor causing the loss of this vitamin. However, the influence of other factors present in unpasteurised cream cannot be ruled out, in particular the enzymatic activity of yeast and lactic acid bacteria, to which retinol and riboflavin were found to be more resistant.

Factors affecting the vitamin content of butter include a complex of physical changes that occur during storage, including ageing, sedimentation (Anema, 2019), as well as a number of chemical changes, including colour change due to non-enzymatic browning reactions (Karlsson et al., 2019). Although it is believed that the main vitamin losses during storage of dairy products may be caused by oxidation and exposure to light (Kilic-Akyilmaz et al., 2022), it is quite difficult to determine the objective cause of tocopherol degradation during storage of goat milk butter in our experiment. The observed changes in vitamin concentrations during the storage of goat milk butter are important for understanding the influence of various factors on quality and stability during shelf life.

Another important criterion of the quality of butter is the content of macro- and microelements in it, which can enter the consumer's body. Analysis of literature data showed that the shelf life of the mineral composition of butter has practically not been studied. It is expected that macro-, microelements and heavy metals, unlike vitamins, belong to stable elements that are not able to decompose during the storage period of butter. Therefore, their dynamics in butter depended little on this factor in our experiment.

Considering that the salting of goat milk butter was not carried out during the production process, the sodium level in it was very low, which is in line with a healthy diet, since its high content in the human diet is a risk factor for hypertension and impaired lipid distribution in body tissues (Liu et al., 2023; Wang et al., 2025).

As for macronutrients such as phosphorus and calcium, their ratio in goat milk butter did not meet the requirements for the human diet. However, due to the low consumption, butter is not the main source of these minerals and has little impact on the total ratio of mineral components in the diet (Gutiérrez et al., 2020). The content of potassium, magnesium, as well as microelements such as zinc, iron, manganese, copper, molybdenum, cobalt and selenium in butter from goat milk indicates their low intake into the body of goats with feed and water, and therefore excretion with milk and accumulation in milk fat. This is confirmed by the results of the mineral composition of brine Feta cheese, Chevre cheese with white noble mould, and hard Alpine and Yoghurt cheeses made from goat milk from the same farm (Davydovych et al., 2026a, 2026b). Such a comprehensive approach to the analysis of the mineral composition of dairy products produced on a single farm allows us to confirm individual criteria for their authenticity, as well as traceability in the "farm to fork" chain, which is consistent with the One Health concept (Zhang et al., 2024).

Priority indicators of chemical safety of food products, including butter, include the content of minerals, which in high doses can exhibit the properties of heavy metals (Mititelu et al., 2025). The entry of heavy metals into milk and its processed products depends on their concentration in the tissues of ruminants, in particular goats (Njoga et al., 2021). Excessive or prolonged consumption of microelements such as Zn, Fe, Cu, Mn, Co, Mo and Cr can lead to adverse effects on human health. Toxic heavy metals/metalloids are elements that have no clinically proven benefit for humans and livestock, but even in small doses can exhibit carcinogenic, teratogenic and toxic effects on the body in both the short and long term (Ezedom et al., 2020; Nkwunonwo et al., 2020). Elements such as arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) are among the ten major heavy metals of serious public health concern. (Koch et al., 2022).

Determination of the content of mineral components in butter is mainly carried out to assess its safety in terms of heavy metals (Bilandžić et al., 2014). In this study, the content of manganese, molybdenum, aluminium, nickel and chromium in butter significantly exceeded the data obtained in our study, which is associated with the influence of technological conditions of milk production and processing and feeding of ruminants. In other studies, Fahmy & Abdel-Fattah, (2008) and Leggli et al. (2011) found Zn content in butter at levels of 0.086 and 1.36 mg/kg, which is lower than our data. A similar analysis of butter, given in Vahedi et al., (2015), indicates that the permissible limit of accumulation of lead, cadmium, copper and iron in butter is exceeded, which also exceeds the data of butter used in our experiment. Moreover, the authors emphasise the dependence of the solubility of mineral elements in milk whey and their transfer to buttermilk. This work notes that a certain part of heavy metals can be washed out of the butter during its washing with water, or, conversely, enter the butter with washing water (Alwazeer et al., 2022). This statement does not contradict the results of the analysis of the mineral composition of the butter in our experiment, and even more so, it indirectly confirms the purity of the water in terms of the content of heavy metals, which is used in the production process of this product.

Conclusions

Storage of butter from unpasteurised goat milk cream in a refrigerator at a temperature of 4 ± 1 ºC for 20 days did not affect the content of retinol and riboflavin, but caused a decrease in the level of tocopherol on the 10th day by 10.23% and on the 20th day by 14.42%. The shelf life of the butter did not affect the content of macro-, microelements and heavy metals in it. The level of macroelements in the butter corresponded to the following order of decreasing concentration: P < Na < K < Ca < Mg. The content of microelements in descending order was as follows: Zn < Fe < Cu < Mn = Mo < Co < Se. Among heavy metals, the content of arsenic and antimony in the butter was below the detection limit, and the elements were located in the following order: Al < Pb = Ni < Cr < Hg < Cd < As = Sb.

According to the hazard coefficient, heavy metals found in the goat milk butter were in the following order: Hg < Pb < Cd = Cr < Al < Ni < Zn < Cu = Fe < Mn < Mo < Co. The target hazard quotient (THQ) of heavy metals in no case exceeded 1, which indicates that goat milk butter is safe for the health of consumers even with a maximum consumption of 30 g per day.

The obtained results of butter analysis showed its high biological value and stability of vitamin and mineral composition during a storage period of 20 days in refrigerated form, which can serve as a criterion of proper quality and safety, as well as the ecological well-being of the region.

The authors declare that they have no potential conflict of interest.

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