

*Scifood*

vol. 20, 2026, p. 119-134

<https://doi.org/10.5219/scifood.92>

ISSN: 2989-4034 online

<https://scifood.eu>

© 2026 Authors, License: CC BY-NC-ND 4.0

Received: 6.11.2025

Revised: 17.2.2026

Accepted: 19.2.2026

Published: 23.2.2026



## The influence of ripening duration on the mineral composition of craft hard goat cheeses

*Viktor Davydovych, Larysa Shevchenko, Nataliia Slobodianiuk, Nataliia Holembovska, Oksana Pylypchuk, Vasyl Shynkaruk, Alona Altanova, Mykola Gruntkovskiy*

### ABSTRACT

The production of craft goat cheeses is becoming increasingly widespread worldwide and in Ukraine's domestic market. A distinctive feature of such hard goat cheeses is their production from unpasteurised milk, which imparts a unique combination of flavour, aroma, and beneficial microflora. In addition, goat milk cheeses are a source of nutritional and biologically active compounds, including macro- and microelements, as well as potentially toxic contaminants, including heavy metals. This involves controlling their accumulation during the ripening process and assessing quality and safety. The study employed craft hard goat cheeses, namely Alpine and Yoghurt varieties, made from unpasteurised goat milk, which ripen with the involvement of *Acarus siro mites* for 12 and 18 months, respectively. Optical emission spectrometry was used to study the mineral composition of cheeses. During ripening, an increase in the content of macroelements (Ca, P, Na, K, Mg) and microelements (Zn, Fe, Mn, Cu, Mo, Co) was detected in Alpine and Yoghurt cheeses. In terms of the level of accumulation in Alpine and Yoghurt cheeses, the series of macroelements took the following form: Ca > P > Na > K > Mg, and microelements, respectively: Zn > Fe > Mn = Cu > Mo > Co > Se. In addition to essential elements, during the ripening process of Alpine and Yoghurt cheeses, heavy metals accumulated in the following order: Al > Pb = Ni > Cr > Cd > Hg > As/Sb, but their content did not exceed the permissible regulatory values. Research results indicate that hard craft goat cheeses, Alpine and Yoghurt, are a safe source of essential elements for the human body, and their mineral composition can serve as a component of geographical and ecological criteria for craft production.

**Keywords:** Alpine cheese, Yoghurt cheese, macronutrients, micronutrients, heavy metals.

### INTRODUCTION

Milk and dairy products have been, are, and will remain an important source of beneficial microflora [1], [2], as well as proteins, lipids, fatty acids, vitamins, and mineral compounds for humans throughout their entire lifespan [3], [4], [5]. They are a source of iron, calcium, zinc, copper, and other elements that function as cofactors in metabolic processes, and in optimal quantities, they are physiologically essential for both animals and humans [6]. Cheese is able to provide the human body with calcium by 58%, phosphorus by 32%, zinc by 23%, potassium and sodium by 17% and magnesium by 15% [7], [8].

Given the significant proportion of mineral components in dairy products, including cheeses, it is essential to monitor their content at different stages of ripening. In addition, the presence of available minerals in dairy products, in particular, in cheeses, contributes to improving the health of the population by preventing mineral metabolism disorders, improving the intestines, preventing the development of urolithiasis and gallstone disease and cardiovascular diseases [9].

In addition to beneficial mineral compounds, including macro- and microelements, hard cheeses can accumulate heavy metals such as lead, cadmium, nickel, antimony, chromium, mercury, and arsenic. The biological role of these elements has not been proven, and their potential to harm human health has been identified even at trace levels [10], [11]. As a rule, the content of heavy metals in milk is minimal, but during the production of hard cheeses, conditions arise when they can concentrate in the dry matter. Therefore, there is a need to control them at various stages of cheese ripening to ensure their safety [12]. It is believed that the mineral content serves as a criterion for soil, water, and feed contamination and as an indicator of the geographical location of areas for milk and cheese production [13].

Most hard cheeses produced using industrial technologies are monitored for the content of essential minerals and certain heavy metals; however, in craft production, where goat milk is used as a raw material, this issue has been little studied.

Given that the production of hard-craft goat cheeses is becoming increasingly popular in domestic and global markets, there is a need to develop criteria for authenticity and to determine quality and safety indicators [14]. This is also facilitated by the expansion of the range of goat cheeses made from unpasteurised milk, which, on the one hand, promotes producers' own craft products and, on the other hand, increases consumer demand for refined cheeses. Hard goat cheeses are especially valued for their high protein, trace element, and biologically active substance content, as well as their hypoallergenic properties [15].

Determining the authenticity of cheeses made from the milk of small ruminants is a pressing issue addressed by leading scientists [16], as it is associated with their original recipes and manufacturing technologies, as well as their unique taste, aroma, and chemical composition [17]. Determining the content of macro-, microelements, and heavy metals is a necessary condition for assessing the quality and safety of craft goat hard cheeses, taking into account their ripening period. There are few such studies in the literature, and they do not reveal features of the accumulation of mineral components in hard cheeses made from unpasteurised goat milk during ripening, nor address issues of their quality and safety.

## Scientific Hypothesis

**Hypothesis 1:** The duration of ripening significantly influences the concentration, distribution, and ratios of essential macroelements, microelements, and selected heavy metals in craft hard goat cheeses (Alpine and Yoghurt) produced from unpasteurised goat milk.

**Hypothesis 2:** Changes in the mineral composition of craft hard goat cheeses during ripening can be used to evaluate their nutritional value and safety and to identify characteristic mineral profiles that may serve as indicators of product authenticity related to production conditions.

## Objectives

**Main objectives:** to determine the influence of ripening time on the mineral composition of hard craft goat cheeses, Alpine and Yoghurt. To determine the intensity of accumulation of essential elements and heavy metals in hard goat cheeses. **Auxiliary tasks:** to assess the biological value and safety of hard craft goat cheeses.

## MATERIALS AND METHODS

### Samples

**Samples description:** For the research, average samples of hard craft goat cheeses from Alpine and Yoghurt were used. After the production of both cheese types, the batch was divided into three sub-batches, from which composite samples were taken in triplicate over the ripening period.

**Sample collection:** For the study, five cheese wheels of each cheese type were randomly selected, with ripening period taken into account.

**Samples preparation.** Samples of Alpine cheese were analysed on the 7th day, the 6th month, and the 12th month of ripening, while Yoghurt cheese samples were analysed on the 7th day, the 6th month, and the 18th month of ripening. For each cheese type, composite samples were prepared from five cheese wheels, each weighing 200 g. The collection of composite cheese samples was performed by vertically sectioning each wheel, allowing consideration of mineral content from both the upper and lower rind surfaces and the core. Chemically clean and sterile instruments were employed for sample collection. The cheese samples were packaged and transported to the analytical laboratory in vacuum-sealed bags under refrigerated conditions. Homogenisation of the samples was conducted under controlled laboratory conditions.

**Number of samples analyzed:** In total, 15 units of Alpine cheese and 15 wheels of Yoghurt cheese were used in the experiment. The comparison of macro- and microelements as well as heavy metal content was carried out on five samples, each analysed in triplicate, for each cheese variety at every ripening stage (2 cheese types × 3 ripening stages × 5 biological replicates × triplicate measurements).

### Chemicals

For the analyses, certified multi-element and single-element standard solutions for atomic emission spectrometry, produced by Merck (Germany) and certified for ion content, were employed. These were diluted to obtain concentrations of the same order of magnitude as the upper limits of the element content range. Cheese samples weighing 0.3–0.5 g were treated with 6 cm<sup>3</sup> of concentrated nitric acid (HNO<sub>3</sub>, Merck, Germany) and 3 cm<sup>3</sup> of deionised water (serving as a reagent blank). The resulting mixture was then filtered to a final volume of 50 cm<sup>3</sup> using Sartorius filters (France). For quality control, the certified reference material (ERM CA 011c) was used. To monitor sensitivity fluctuations in ICP-OES analysis, an internal standard solution of indium at 20 µg/L (ROTI@STAR) was used. Standard solutions were diluted with 2% nitric acid. All reagents used in the study were of analytical grade.

### Animals, Plants and Biological Materials

Alpine cheese and Yoghurt cheese (Eco Farm "Zhuravka" Kyiv region, Ukraine), cheese starters Alp D (Danisco France SAS, France), TOM V-02 (IGEA Cultures, Italy), YF-L 812 (Chr. Hansen, Denmark), liquid rennet enzyme Rennet Liquid 92/8 (Pamir Service, Kyiv, Ukraine).

For both cheese varieties, goat milk was obtained from a single farm and herd.

### Instruments

The sample preparation was carried out using a closed-type mineraliser (Microwave Laboratory Systems, Milestone, Italy). 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 studied using an ICP optical emission spectrometer (ICP-OES) PlasmaQuant PQ 9000 Analytik Jena (Germany). The mercury content in the cheeses was determined using a single-beam atomic absorption spectrophotometer equipped with two consecutive measurement cells. Determination of mercury content in cheese samples was performed using a mercury analyser, the Milestone DMA-80 (Italy). A refrigerator and freezer (Liebherr, Switzerland) were used to store the samples.

### Laboratory Methods

The study of the content of mineral elements: calcium, phosphorus, sodium, potassium, magnesium, copper, zinc, iron, manganese, molybdenum, cobalt, lead, cadmium, mercury, chromium, aluminium, nickel, selenium, antimony, and arsenic in the samples was carried out using optical emission spectrometry according to PV.DNDILDVSE 7.2-1/1-21 (Determination of micro- and macroelements in food products, feed, premixes, vitamin supplements for animals and poultry by the optical-emission inductively coupled plasma method). The analytical signals were processed automatically using the spectrometer's software, employing calibration curves that accounted for background correction and, when necessary, the inter-elemental interference.

**Measurement parameters:** For ICP-OES analysis, the following plasma parameters were applied: wavelength range 160–900 nm, wavelength accuracy < 0.4 pm (picometer), resolution 1:145000, plasma power 1200 W, and nebuliser gas flow 0.5 L/min, using argon. Auxiliary and nebuliser gas flows were also argon, 12 L/min at 6 bar. The sample introduction system consisted of a concentric nebuliser and a cyclonic spray chamber, with axial observation mode. The analytical wavelengths for each element and the corresponding limits of detection are presented in Table 1.

The integration time was 3 seconds per channel, with 3 replicates (3 measurements) performed for each sample. Reagent blanks and calibration standards were analysed after every 10 samples.

Mercury content in the cheese samples was determined using atomic absorption spectrophotometry in accordance with the recommendations of document PV.DNDILDVSE 7.2-1/1-13 (Determination of mercury in raw materials, animal and plant products, feed, water, biomaterials, alcoholic beverages, and soil by atomic absorption spectrometry).

During the analysis, the manufacturer's software for the ICP instrument, OES Software Aspect PQ, DMA 80 evo, version 03-E (20221-01-21), was used.

The determination of mercury content in cheeses was carried out using the DMA 80 analyzer; for this purpose, 0.08-0.12 g of cheese was taken. For the study, a calibration standard mercury solution ("Fluka", "Merck" Germany) with a certified mercury ion content of 1 g/l was used.

The maximum initial temperature was 250 °C, with a cleaning time of 60 seconds. Grubbs' test was applied as the criterion for identifying outliers.

To assess the risk of heavy metals to consumers, the estimated daily intake (EDI) of the most hazardous elements exhibiting heavy metal characteristics was calculated using the following formula [10]:

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

where  $C_m$  – the metal content in cheese, mg/kg (for the calculation, the mineral content in Alpine cheese at 12 months and Yoghurt cheese at 18 months of ripening was used);

$W_f$  – the average daily cheese consumption per person (taken as the maximum, 100 g);

$BW$  – the body weight of an adult (70 kg).

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

$THQ = EDI / RFD_o$ , where

$RFD_o$  – 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  $\geq 1$  suggests potential adverse effects [18].

**Table 1** Wavelengths and detection limits of mineral elements.

Element	Parameter	
	Wavelength, nm	Limit of quantification, $\mu\text{g}/\text{kg}$
Ca	315.887	5.0
P	178.287	3.0
Na	589.592	1.0
K	766.490	5.0
Mg	383.826	5.0
Zn	206.191	5.0
Fe	259.940	5.0
Mn	257.610	2.0
Cu	325.754	2.0
Mo	202.030	0.1
Co	228.616	0.01
Se	196.090	1.0
Al	308.215	2.0
Pb	220.353	1.0
Ni	234.604	1.0
Cr	267.176	0.1
Cd	214.438	0.1
Hg	253.650	0.01
As	193.696	1.0
Sb	206.833	1.0

**Table 2** Furnace temperature programme during the analysis.

Position	Time	Temperature, $^{\circ}\text{C}$
1	00:00:05	200
2	00:00:10	190
3	00:00:10	650
4	00:01:30	650

### Description of the Experiment

**Study flow:** The experiment utilised two types of hard craft cheeses made from unpasteurised goat's milk. The wheels of Alpine and Yoghurt cheeses were made with an average weight of 4.5–5.0 kg. Milk from Anglo-Nubian goats, which graze on natural pastures during the warm season, was used to produce the cheeses. Both types of cheeses were made according to the recipe described earlier [19] (Figure 1 and Figure 2).

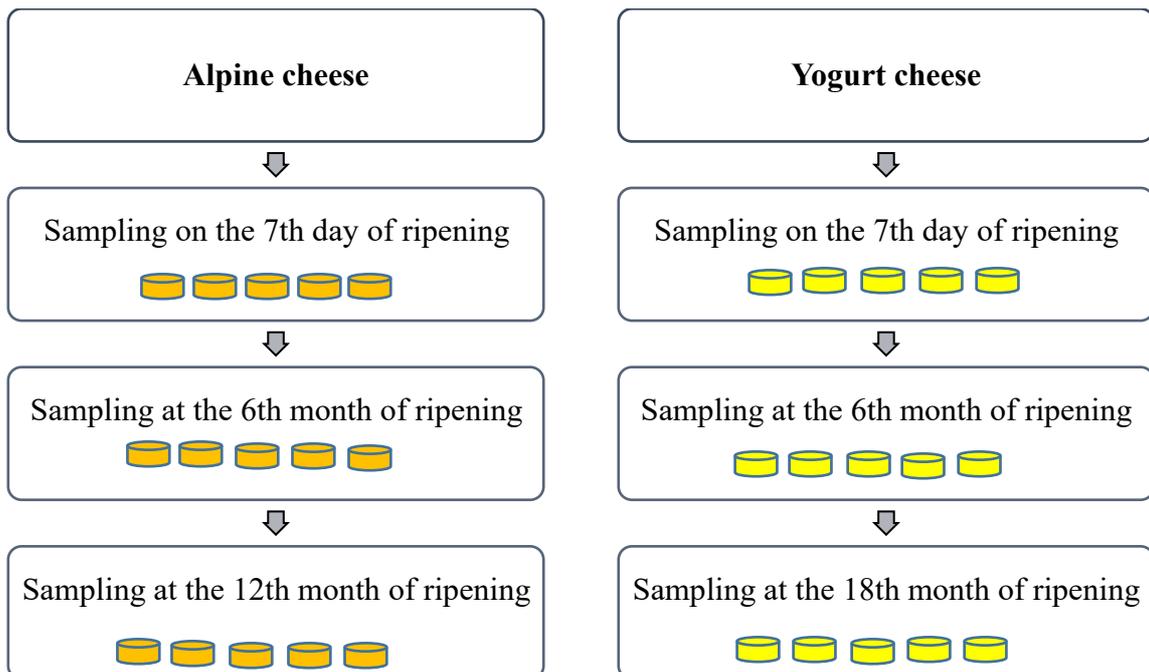


**Figure 1** Alpine cheese aged 12 months.



**Figure 2** Yogurt cheese aged 18 months.

The scheme for sampling the cheeses for analysis is shown in Figure 3.



**Figure 3** Scheme of cheese sampling for mineral composition analysis.

A limitation of this study is the use of cheeses made on a single farm from the milk of a single herd of Anglo-Nubian goats.

### Quality Assurance

**Number of repeated analyses:** 5 samples were used in each study.

**Number of experiment replication:** 1.

**Reference materials:** -

**Calibration:** Each instrument was calibrated before each experiment, and calibration checks were performed regularly to maintain measurement accuracy. Each instrument was calibrated before each experiment, and calibration checks were performed regularly to maintain measurement accuracy.

**Laboratory accreditation:** Determination of the content of mineral elements in craft goat cheeses was performed 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 17025:2019. The scope of accreditation includes research into food products, raw materials of animal, plant, and biotechnological origin, feed, feed raw materials, and vitamin preparations for quality and safety, molecular genetic research – 866 indicators, 219 – sanitary and hygienic indicators; diagnostics of animal diseases of infectious and non-infectious etiology – 235 diseases using 53 methods.

### Data Access

The data supporting the findings of this study are not publicly available.

### Statistical Analysis

The statistical analysis of the obtained results was performed using one-way analysis of variance (ANOVA). The content of macro-, microelements, and heavy metals in hard goat cheeses, Alpine, and Yoghurt, was compared within each name depending on the ripening period. The analysis was performed using Microsoft Excel 2021 and XLSTAT. The data in the tables are presented as  $x \pm SD$  (mean  $\pm$  standard deviation). Differences between the variants were considered significant when  $P < 0.05$ , using the Tukey test.

## RESULTS AND DISCUSSION

The ripening period contributed to increased concentrations of macro- and microelements in hard goat cheeses. The calcium content in Alpine cheese increased by 30.85% at the 6th month of ripening, and by 40.44% at the 12th month compared to the 7-day-old cheese (Table 2). The phosphorus content also depended on the ripening period of Alpine cheese, increasing by 34.97% at the 6th month of ripening and remaining at this level until the 12th month. The ratio of calcium to phosphorus at the 7th day of ripening was 1:1.22, at the 6th month of ripening, 1:1.18, and at the 12th month of ripening, 1:1.26.

The sodium concentration increased by 66.85% in 6-month-old cheese and by 1.9 times in 12-month-old cheese compared to 7-day-old cheese. The potassium content in Alpine cheese also increased during ripening, but to a lesser extent than sodium. At the 6th month, the potassium content in Alpine cheese increased by 27.59%, and at the 12th month, by 40.01% compared to the initial value (Table 3). The ratio of sodium to potassium in Alpine cheese directly depended on its age and was 1:3.02 on the 7th day of ripening, 1:3.94 on the 6th month of ripening, and 1:4.20 on the 12th month of ripening.

In mature and old-ripened Alpine cheese, the magnesium content among macroelements was the lowest; however, an increase in its concentration during the ripening process was found within 16.35% compared to young cheese.

Alpine goat cheese is a source not only of macroelements but also of microelements. This is evidenced by increases in zinc content during ripening of 37.50–47.50%, iron of 22.07–31.10%, and manganese of 2.06–2.42 times (Table 3).

Among the studied trace elements, zinc had the highest content in Alpine cheese, followed by iron; its concentration depended directly on the cheese's ripening period and was similar to that of zinc.

The manganese and copper content in young Alpine cheese fluctuated at similar levels, but at 6 months, both trace elements showed a 2.06-fold increase and a 33.04% increase, respectively. Later, at 12 months of age, the manganese content in this cheese stabilised, and the copper content increased 2.58-fold compared to the young cheese.

The molybdenum content in Alpine cheese during the ripening period, from 7 days to 6 months of age, remained almost unchanged. However, at 12 months of age, a 58.33% increase in its amount was noted.

The concentration of cobalt in Alpine cheese was the lowest among the levels of the studied trace elements and increased by 2.55–2.81 times in mature and old age compared to young (Table 3). Selenium in Alpine cheese was negligible, below the device's sensitivity limit.

**Table 3** The content of macro- and microelements depending on the ripening period of hard goat cheese Alpine,  $x \pm SD$ ,  $n = 5$ .

Indicator	Cheese ripening period		
	7 days	6 months	12 months
<b>Macronutrients</b>			
Ca, mg/kg	95.71 ± 5.95 <sup>a</sup>	125.24 ± 16.19 <sup>b</sup>	134.42 ± 2.65 <sup>b</sup>
P, mg/kg	78.35 ± 5.17 <sup>a</sup>	105.75 ± 2.30 <sup>b</sup>	106.60 ± 1.32 <sup>b</sup>
Na, mg/kg	46.36 ± 6.61 <sup>a</sup>	77.35 ± 4.15 <sup>b</sup>	90.42 ± 2.33 <sup>c</sup>
K, mg/kg	15.37 ± 0.41 <sup>a</sup>	19.61 ± 0.69 <sup>b</sup>	21.52 ± 0.83 <sup>c</sup>
Mg, mg/kg	6.79 ± 0.17 <sup>a</sup>	7.90 ± 0.26 <sup>b</sup>	8.07 ± 0.64 <sup>b</sup>
<b>Micronutrients</b>			
Zn, mg/kg	0.40 ± 0.03 <sup>a</sup>	0.55 ± 0.02 <sup>b</sup>	0.59 ± 0.03 <sup>b</sup>
Fe, µg/kg	44.40 ± 3.51 <sup>a</sup>	54.20 ± 8.58 <sup>b</sup>	58.21 ± 6.98 <sup>b</sup>
Mn, µg/kg	5.37 ± 0.34 <sup>a</sup>	11.05 ± 1.44 <sup>b</sup>	12.98 ± 1.26 <sup>b</sup>
Cu, µg/kg	4.51 ± 0.70 <sup>a</sup>	6.00 ± 0.21 <sup>b</sup>	11.62 ± 1.10 <sup>c</sup>
Mo, µg/kg	0.36 ± 0.04 <sup>a</sup>	0.48 ± 0.13 <sup>ab</sup>	0.57 ± 0.05 <sup>b</sup>
Co, µg/kg	0.027 ± 0.010 <sup>a</sup>	0.069 ± 0.005 <sup>b</sup>	0.076 ± 0.004 <sup>b</sup>
Se, µg/kg	<1.00	<1.00	<1.00

Note: different superscript letters indicate values that were significantly different in the same row of the table ( $P < 0.05$ ) according to the results of comparison using the Tukey test.

Among the heavy metals in Alpine cheese, aluminium accounted for the largest share; its content in mature cheese did not differ significantly, but in old-ripened cheese it exceeded the corresponding indicator in young cheese by 45.56% (Table 4).

Lead and nickel ranked second in detection in Alpine cheese. As for the concentration of lead, the ripening period of the cheese had practically no effect on this indicator, while the nickel content increased with increasing ripening period of the cheese, in particular, by 1.70 times at the 6th month of ripening, and by 2.34 times at the 12th month compared to young cheese.

The chromium content in mature Alpine cheese did not differ from that of young cheese, but increased by 27.87% at 12 months of age.

The contamination of Alpine cheese with cadmium and mercury was in the same range of values, but the concentration of cadmium, like lead, did not significantly depend on the ripening period, and the concentration of mercury increased by 2.83–4.33 times compared to young cheese (Table 4). The contamination of Alpine cheese with arsenic and antimony was not established, as their concentrations were below the device's detection limit.

**Table 4** Concentrations of heavy metals depending on the ripening period of hard goat cheese Alpine,  $x \pm SD$ ,  $n = 5$ .

Indicator	Cheese ripening period		
	7 days	6 months	12 months
Al, µg/kg	26.37 ± 3.80 <sup>a</sup>	29.36 ± 2.96 <sup>a</sup>	38.41 ± 6.10 <sup>b</sup>
Pb, µg/kg	2.25 ± 0.09 <sup>a</sup>	2.36 ± 0.56 <sup>a</sup>	2.52 ± 0.51 <sup>a</sup>
Ni, µg/kg	1.83 ± 0.05 <sup>a</sup>	3.11 ± 0.66 <sup>b</sup>	4.28 ± 0.72 <sup>c</sup>
Cr, µg/kg	1.22 ± 0.08 <sup>a</sup>	1.37 ± 0.07 <sup>ab</sup>	1.56 ± 0.16 <sup>b</sup>
Cd, µg/kg	0.16 ± 0.03 <sup>a</sup>	0.18 ± 0.01 <sup>a</sup>	0.21 ± 0.02 <sup>a</sup>
Hg, µg/kg	0.06 ± 0.01 <sup>a</sup>	0.17 ± 0.03 <sup>b</sup>	0.26 ± 0.09 <sup>b</sup>
As, µg/kg	<1.00	<1.00	<1.00
Sb, µg/kg	<1.00	<1.00	<1.00

Note: different superscript letters indicate values that were significantly different in the same row of the table ( $P < 0.05$ ) according to the results of comparison using the Tukey test.

The dynamics of the mineral composition of Yoghurt cheese largely depended on the ripening period and were similar to those of Alpine cheese. This is evidenced by the calcium content, which in Yoghurt cheese increased in direct proportion to its ripening period: at the 6th month, by 52.29% ( $P < 0.05$ ), at the 18th month, by 78.29% ( $P < 0.05$ ) compared to young cheese. A similar pattern was observed for phosphorus, with its level increasing by 21.14% ( $P < 0.05$ ) in 6-month cheese and by 46.99% ( $P < 0.05$ ) in 18-month cheese (Table 5). At the same time,

the ratio of calcium to phosphorus in 7-day cheese was 1:1.01, 6-month cheese - 1:1.27, and 18-month cheese - 1:1.23.

**Table 5** The content of macro- and microelements, depending on the ripening period of hard goat cheese Yoghurt,  $\bar{x} \pm SD$ ,  $n = 5$ .

Indicator	Cheese ripening period		
	7 days	6 months	18 months
	<b>Macronutrients</b>		
<b>Ca, mg/kg</b>	80.72 ± 10.93 <sup>a</sup>	122.93 ± 10.75 <sup>b</sup>	143.92 ± 9.94 <sup>c</sup>
<b>P, mg/kg</b>	79.84 ± 8.32 <sup>a</sup>	96.72 ± 9.05 <sup>b</sup>	117.36 ± 2.55 <sup>c</sup>
<b>Na, mg/kg</b>	44.49 ± 7.68 <sup>a</sup>	61.85 ± 3.24 <sup>b</sup>	112.78 ± 8.98 <sup>c</sup>
<b>K, mg/kg</b>	9.56 ± 0.38 <sup>a</sup>	18.36 ± 1.07 <sup>b</sup>	23.33 ± 2.51 <sup>c</sup>
<b>Mg, mg/kg</b>	3.23 ± 0.66 <sup>a</sup>	6.37 ± 0.39 <sup>b</sup>	7.35 ± 0.86 <sup>b</sup>
	<b>Micronutrients</b>		
<b>Zn, mg/kg</b>	0.28 ± 0.02 <sup>a</sup>	0.52 ± 0.07 <sup>b</sup>	0.55 ± 0.08 <sup>b</sup>
<b>Fe, µg/kg</b>	31.26 ± 6.02 <sup>a</sup>	39.92 ± 3.75 <sup>a</sup>	66.40 ± 10.26 <sup>b</sup>
<b>Mn, µg/kg</b>	5.32 ± 0.29 <sup>a</sup>	7.62 ± 1.23 <sup>b</sup>	10.47 ± 1.59 <sup>c</sup>
<b>Cu, µg/kg</b>	3.27 ± 0.04 <sup>a</sup>	5.36 ± 0.39 <sup>b</sup>	15.58 ± 3.39 <sup>c</sup>
<b>Mo, µg/kg</b>	0.52 ± 0.06 <sup>a</sup>	0.72 ± 0.14 <sup>b</sup>	0.83 ± 0.05 <sup>b</sup>
<b>Co, µg/kg</b>	0.009 ± 0.001 <sup>a</sup>	0.032 ± 0.004 <sup>b</sup>	0.044 ± 0.003 <sup>c</sup>
<b>Se, µg/kg</b>	<1.00	<1.00	<1.00

Note: different superscript letters indicate values that were significantly different in the same row of the table ( $P < 0.05$ ) according to the results of comparison using the Tukey test.

The content of such common minerals as sodium and potassium in Yoghurt cheese increased in direct proportion to the period of its ripening. Thus, at the 6th month of ripening, the sodium content in Yoghurt cheese increased by 39.02% ( $P < 0.05$ ), potassium – by 1.92 times ( $P < 0.05$ ), while at the 18th month of ripening, the sodium concentration increased by 2.53 times ( $P < 0.05$ ), and potassium – by 2.44 times ( $P < 0.05$ ) compared to the 7-day-old cheese. The ratio of sodium to potassium in young Yoghurt cheese was 1:4.65, mature – 1:3.37, and old-ripened – 1:4.83.

The magnesium content in Yoghurt cheese also increased with increasing age within 1.97-2.27 times ( $P < 0.05$ ) compared to young cheese (Table 5).

Among the list of studied microelements in Yoghurt cheese, as in Alpine cheese, zinc was the most significant, with its content increasing by 1.86–1.96 times ( $P < 0.05$ ) during the ripening process compared to young cheese. As for iron, an increase in its content was noted only in old-ripened Yoghurt cheese by 2.12 times ( $P < 0.05$ ) compared to young cheese.

Yoghurt cheese during ripening was similar and was characterised by an increase in manganese content of 43.23% ( $P < 0.05$ ) at the 6th month of ripening, and 1.97 times ( $P < 0.05$ ) at the 18th month, while the copper content increased by 1.64 times ( $P < 0.05$ ) and 4.76 times ( $P < 0.05$ ), respectively, compared to young cheese.

Yoghurt cheese increased significantly only by the 6th month of ripening, by 38.46% ( $P < 0.05$ ), and remained at that level by the 18th month. Cobalt is a trace element that occupies the smallest share in goat cheeses, and its content gradually increased by the 6th month of ripening by 3.55 times ( $P < 0.05$ ) and by the 18th month of ripening by 4.89 times ( $P < 0.05$ ) compared to the 7-day-old cheese. The selenium content in Yoghurt cheese did not exceed the device's sensitivity limit and was <1.00 µg/kg.

Among the heavy metals in Yoghurt cheese, aluminium was the main one; its content increased by 1.88 times ( $P < 0.05$ ) at 6 months of ripening and by 2.26 times ( $P < 0.05$ ) at 18 months compared to young cheese. Lead and nickel ranked second in terms of contamination in Yoghurt cheese. The lead content in this cheese increased by 33.69% ( $P < 0.05$ ) only at 18 months of ripening, and the nickel content increased by 2.54 times ( $P < 0.05$ ) at 6 months of ripening and by 3.47 times ( $P < 0.05$ ) at 18 months compared to young cheese (Table 6).

As for chromium in Yoghurt cheese, its content also increased by 2.02 times ( $P < 0.05$ ) at the 6th month of ripening and by 2.24 times ( $P < 0.05$ ) at the 18th month of ripening compared to young cheese. However, this cannot be said of the contamination of Yoghurt cheese with cadmium, the level of which remained practically unchanged throughout ripening.

The lowest concentration of all the studied heavy metals was in Yoghurt cheese, but its content increased in mature cheese by 3.25 times ( $P < 0.05$ ) and in old-ripened cheese by 5.50 times ( $P < 0.05$ ) compared to young cheese.

**Table 6** Heavy metal content depending on the ripening period of hard goat cheese Yoghurt,  $x \pm SD$ ,  $n = 5$ .

Indicator	Cheese ripening period		
	7 days	6 months	18 months
Al, $\mu\text{g/kg}$	$13.76 \pm 3.21^a$	$25.83 \pm 1.55^b$	$31.18 \pm 3.88^b$
Pb, $\mu\text{g/kg}$	$1.84 \pm 0.36^a$	$2.24 \pm 0.18^{ab}$	$2.46 \pm 0.19^b$
Ni, $\mu\text{g/kg}$	$0.79 \pm 0.13^a$	$2.01 \pm 0.39^b$	$2.74 \pm 0.78^b$
Cr, $\mu\text{g/kg}$	$0.58 \pm 0.15^a$	$1.17 \pm 0.05^b$	$1.30 \pm 0.03^b$
Cd, $\mu\text{g/kg}$	$0.19 \pm 0.01^a$	$0.20 \pm 0.03^a$	$0.22 \pm 0.04^a$
Hg, $\mu\text{g/kg}$	$0.04 \pm 0.01^a$	$0.13 \pm 0.04^b$	$0.22 \pm 0.06^c$
As, $\mu\text{g/kg}$	<1.00	<1.00	<1.00
Sb, $\mu\text{g/kg}$	<1.00	<1.00	<1.00

Note: different superscript letters indicate values that were significantly different in the same row of the table ( $P < 0.05$ ) according to the results of comparison using the Tukey test.

Among the elements classified as heavy metals are arsenic and antimony, but their concentrations in Yoghurt cheese were below the device's sensitivity limit and were  $<1.00 \mu\text{g/kg}$ .

A comparison of the risk of heavy metal exposure in humans from the consumption of hard goat cheeses, Alpine and Yogurt, indicated that the estimated daily intake (EDI) of Zn, Fe, Mn, Cu, Mo, Co, Al, Pb, Ni, Cr, Cd, and Hg ranged from  $-7.78$  to  $-4.26 \text{ lg mg/kg}$  body weight per day and from  $-8.44$  to  $-2.43 \text{ lg mg/kg/day}$ , respectively (Table 7).

**Table 7** Risk assessment of craft goat cheeses, Alpine and Yogurt, for consumer health.

Element	RFD <sub>0</sub>	Parameter			
		Alpine cheese		Yogurt cheese	
		EDI, lg	THQ	EDI, lg	THQ
Zn	0.3	-6.08	0.000003	-5.55	0.0000026
Fe	0.7	-7.08	0.0000001	-6.93	0.0000001
Mn	0.14	-4.73	0.00013	-3.88	0.00011
Cu	0.04	-7.78	0.0000004	-6.38	0.0000006
Mo	5.0	-6.09	0.0000002	-6.79	0.0000002
Co	30.0	-6.97	0.000000004	-8.44	0.000000002
Al	0.4	-4.26	0.00014	-3.86	0.00011
Pb	0.004	-5.44	0.0010	-2.99	0.0010
Ni	0.02	-5.21	0.0003	-3.51	0.00019
Cr	0.003	-5.65	0.00074	-3.13	0.00062
Cd	0.001	-6.52	0.0003	-3.52	0.0003
Hg	0.0001	-6.43	0.0037	-2.43	0.0031

Note: EDI was calculated in  $\text{lg mg/kg}$  body weight per day.

Accordingly, the target hazard quotient of heavy metals in Alpine and Yogurt cheeses ranged from  $-7.02$  to  $-4.35 \text{ lg}$  and from  $-8.68$  to  $-2.51 \text{ lg}$ , respectively. Thus, the target hazard of elements with heavy-metal properties in both cheeses is significantly below 1. This indicates that even with the consumption of 100 g of each cheese, there is no risk to the consumer's health.

Cheeses are products whose composition depends on a number of factors, including the type and breed of animals from which the raw milk is obtained, feeding and growing conditions [20], and health status. lactating animals [21], [22], cheesemaking technology and production season [23], [24], as well as the cheese microbiome, which determines the direction of chemical reactions and the duration of ripening processes [25], [26].

Mineral components of hard cheeses during ripening are concentrated in dry matter, the content of which increases as the cheeses lose water in the ripening chamber, which is confirmed by our studies of Alpine and Yoghurt cheeses. One of the most important macroelements in cheeses is calcium; therefore, a significant number of works have been devoted to the study of its content in cheeses of various names. A detailed analysis of the mineral composition of 18 cheeses made from buffalo, cow, goat, and sheep milk with varying moisture contents revealed the peculiarities of calcium accumulation. Its content ranged from  $3.18 \text{ g/kg}$  in Mozzarella cheese to  $10.53 \text{ g/kg}$  in Emmental cheese. Cheese samples with lower moisture content ( $<41\%$ ) contained more Ca than those with higher moisture content [27]. A similar pattern was observed in studies [28], indicating that the Ca and P content is higher in hard cheese varieties than in other varieties. This is also associated with the introduction of

phosphate salts, particularly polyphosphates or calcium phosphates, into the cheese mass, as specified in the recipe. In the studied samples of various cheeses, in particular cheeses with a protected designation of origin (PDO), the concentration of essential minerals took the following form: Ca>Na/P>K>Mg, which is due to the influence of cheese moisture and milk type, which is consistent with the results of studies of hard cheeses, Alpine, and Yoghurt.

There are also peculiarities in the concentration of ions of individual elements in cheeses, in particular, K, Na, and Cl are found mainly in the aqueous phase, while Ca, P, and Mg are partially bound to casein micelles. About 1/3 content Ca, 1/2 P, and 2/3 Mg may be in the water milk phase. In cheeses, the mineral content depends mainly on processing. Thus, the content of Ca changes in the following ascending order: milk/fermented milk/fresh cheeses < soft cheeses < semi-hard cheeses < hard cheeses [29]. Considering that during the ripening process of Alpine and Yoghurt cheeses, their moisture content gradually decreased and they moved from the fresh category to the semi-hard and hard categories, the dynamics of calcium content corresponded to the above-mentioned pattern [30].

It should be noted that the calcium and phosphorus content in cheeses made from unpasteurised goat milk, Alpine and Yoghurt, was significantly lower in all ripening periods than in the above-mentioned studies. This is due to the specific composition of cheeses made from unpasteurised goat milk, which do not contain added calcium or phosphorus compounds. This can be considered an advantage rather than a disadvantage of craft cheeses, since excessive calcium concentration in dairy products can increase the risk of the occurrence and complications of pathologies, in particular prostate cancer [31].

It should be noted that our data are consistent with the generally accepted pattern of increasing ash concentration in cheeses during their ripening, since mineral components constitute their basis [32]. The accumulation of mineral elements with increasing ripening time of hard goat cheeses may be due to significant moisture loss, in particular, in Alpiyskiy cheese from the 7th day to the 12th month of ripening, its content decreased from 43.31 to 28.99%, and in Yoghurtovy cheese from the 7th day to the 18th month of ripening - from 46.91 to 29.93% [30]. Such a significant loss of moisture is probably due to the activity of the *A. siro* mite, which takes part in the ripening of these cheeses and, by eating the rind, causes its damage and increases the intensity of moisture evaporation from the cheese heads. However, this statement requires careful verification.

It should also be noted that the content of macro- and microelements in the cheese matrix is unevenly distributed; in particular, in the rind of cheeses, the proportion of calcium can exceed its content in the core by 66 times, phosphorus by 4.4 times, and zinc by 9.9 times [33]. In the study, 38 of the protected-by-name-origin and 9 traditional Italian cheeses showed differences in zinc accumulation. The highest zinc content was found in cheeses made from cow's milk, where it reached values of 1.83–7.75 mg/100 g, while in cheeses made from sheep's milk, 1.34–3.69 mg/100 g, and in cheese from mixed milk, 0.39–4.54 mg/100 g. Most cheeses can meet >10% of the daily human requirement for zinc, as established by the EU (10 mg/day) [34]. In our studies, the zinc content in Alpine and Yoghurt cheeses was significantly lower than in Italian cheeses, which was partly determined by the level of zinc intake into goats' bodies.

In addition to useful minerals, cheeses are also monitored for the presence of toxic compounds, particularly heavy metals. The latter are quite common in the environment and enter ruminant bodies through feed and water, so their accumulation in milk and cheese is an important criterion for assessing safety [35]. A study of cheeses produced in different geographical regions [36] revealed the content of Cd < 0.005–0.012 mg/kg, Cr < 0.02–0.84 mg/kg, Mn – 0.031–1.128 mg/kg, Ni < 0.03–0.67 mg/kg and Pb < 0.01–0.12 mg/kg. Similar levels of heavy metals were found in cheeses from Italy [37] and Serbia [38], but cheeses from southeastern Anatolia [39] significantly exceeded the reported levels. In a study of 79 samples of traditional cheeses produced in two regions of southern Italy, the average Cd content in hard cheeses was 0.004 mg/kg, Hg was 0.08 mg/kg, and Pb was 0.13 mg/kg. In fresh cheeses, the average Cd level reached 0.002 mg/kg, Hg – 0.04 mg/kg, and Pb – 0.07 mg/kg [40]. Another study of the content of heavy metals in cheeses sold on the Turkish market showed the presence of Al at a level of 1752 µg /kg, Cr – 69 µg/kg, Mn – 163 µg/kg, Co – 20 µg/kg, Ni – 131 µg/kg, Cu – 247 µg/kg, As – 59 µg/kg, Cd – 0.005 µg/kg, Hg – 0.02 µg / kg and Pb – 0.05 µg/kg in 51 cheeses. At the same time, no significant differences were found in the cheeses' names, except for Mn, Co, and Cu [41]. Analysis of Turkish craft cheeses Aho, Golot, and Telli showed a significant accumulation of heavy metals, in particular Pb up to 1788.75 µg /kg and Hg – up to 468.71 µg /kg [42]. Mexican craft cheeses from the states of Tabasco and Chiapas contained cadmium at levels of 0.0023 mg/kg, lead at levels of 0.0047–0.0051, nickel at levels of 0.0031–0.0039, copper at levels of 0.0199–0.0202, zinc at levels of 0.1611–0.194, and iron at levels of 61.84–65.76 mg/kg [43]. The data from our study on the content of heavy metals in Alpine and Yoghurt cheeses indicate that, across all ripening periods, they contained significantly lower concentrations of heavy metals than the above-mentioned cheeses. This confirms the absence of significant contamination of the territory, soil, water, and feed with heavy metals in the area of goat cheese production used in our study.

A more objective criterion for the safety of dairy products, and specifically cheeses, is their compliance with the mineral composition requirements outlined in EU Regulation No. 1881/2006 [44]. This document defines the Maximum levels for certain contaminants in foodstuffs in milk for Cd at the level of 0.005 mg/kg and Pb – 0.020 mg/kg [36]. It is important to consider that there is currently no tolerable daily intake (TDI) for heavy metals for humans. Based on the EFSA recommendations, it is possible to determine the threshold values of risk to human health for Cd at the level of 1.0 µg/kg body weight per day [45], Cr – 0.3 mg/kg body weight per day [46], Ni – 13 µg /kg body weight per day [47] and Pb – 3.6 µg /kg body weight per day [48]. In Ukraine, the maximum permissible levels of heavy metals in cheeses are regulated by the State Standards of Ukraine (DSTU), which specify limits for only four elements: Pb (0.3 mg/kg), Cd (0.2 mg/kg), As (0.2 mg/kg), and Hg (0.02 mg/kg of cheese). As shown by the analysis of Alpine and Yogurt cheeses, their concentrations of these metals were considerably lower at all ripening stages, posing no risk to consumer health [49].

Even taking into account that these heavy metals will completely transfer from milk to cheese, the values obtained in our study did not exceed the specified limits. However, this assessment of the level of heavy metals in cheeses is rather conditional, since it does not take into account that the yield of cheese from goat milk is 10-12% and that during its production, whey is removed, and with it a certain amount of dissolved mineral compounds [50]. Therefore, the pattern of accumulation of macro- and microelements and heavy metals in goat craft hard cheeses, such as Alpine and Yoghurt, may be one of the criteria for their authenticity, which is associated with their geographical origin.

## CONCLUSION

Hard craft cheeses made from unpasteurised goat milk, Alpine and Yoghurt, are characterised by a general pattern of mineral accumulation during ripening. With increasing ripening time, the content of macro- and microelements – Ca, P, Na, K, Mg, Zn, Fe, Mn, Cu, Mo, and Co – increased in both cheese varieties. Based on their concentration in Alpine and Yoghurt cheeses, the macroelements can be arranged in the following sequence: Ca>P>Na>K>Mg, while the microelements follow this order: Zn > Fe > Mn = Cu > Mo > Co > Se. During ripening, Alpine and Yogurt cheeses accumulated elements classified as heavy metals—Al, Ni, Cr, and Hg—without exceeding regulatory limits, with their concentrations following the order: Al > Pb = Ni > Cr > Cd > Hg > As/Sb. The obtained research results indicate the biological value of Alpine and Yoghurt cheeses in terms of the content of essential elements and their safety in terms of the content of heavy metals, which can be taken into account when developing criteria for environmental condition of craft production.

## REFERENCES

1. Rogoskii, I., Mushtruk, M., Titova, L., Snezhko, O., Rogach, S., Blesnyuk, O., Rosamaha, Y., Zubok, T., Yeremenko, O., & Nadtochiy, O. (2020). Engineering management of starter cultures in study of temperature of fermentation of sour-milk drink with apiproducs. *Potravinarstvo Slovak Journal of Food Sciences*, 14, 1047–1054. <https://doi.org/10.5219/1437>
2. Savchenko, O., Grek, O., Skuibida, V., Onopriichuk, O., & Pshenychna, T. (2025). Optimisation of parameters for obtaining milk-plant concentrates. *Animal Science and Food Technology*, 126–140. <https://doi.org/10.31548/animal.1.2025.126>
3. Jaafarzadeh, N., Tari, K., Samarghandi, M. R., Fard, M. P., Jorfi, S., Feizi, R., & Mehrbakhsh, M. (2023). Non-carcinogenic risk assessment of cadmium and lead in raw milk from dairy production farms in Iran, using Monte Carlo simulation approach. *Journal of Food Composition and Analysis*, 115, 104864. <https://doi.org/10.1016/j.jfca.2022.104864>
4. Ricardo, T.-G. O., Eduardo, F.-S. M., Rafael, T.-M. A., Moisés, S.-H. I., Verónica, C.-H., Cesar, S.-F., Sofía, G.-G. A., & Eduardo, P.-C. (2024). The leachate from the Urban Solid Waste Transfer Station produces neurotoxicity in Wistar rats. *Toxicology Reports*, 12, 318–324. <https://doi.org/10.1016/j.toxrep.2024.03.002>
5. Alam, M. N. E., Ullah, A. K. M. A., Hosen, M. M., Maksud, M. A., Khan, S. R., Akon, S., Nahar, Q., Jolly, F., & Quraishi, S. B. (2024). Evaluation of essential and trace metals/metalloids distribution and probable human health risk implications from branded liquid and powder milks available in Dhaka City, Bangladesh. *BioMetals*, 37(4), 859–875. <https://doi.org/10.1007/s10534-023-00574-x>
6. Wei, M., Wei, J., & Huang, S. (2025). The association between dietary mineral intake and bone mineral density: a cross-sectional study. *Journal of Health, Population and Nutrition*, 44(1). <https://doi.org/10.1186/s41043-025-01010-1>
7. Van Rossum, C. T. M., Buurma-Rethans, E. J. M., Dinnissen, C. S., Beukers, M. H., Brants, H. A. M., & Ocké, M. C. (2020). The diet of the Dutch: Results of the Dutch national food consumption survey 2012–2016. In RIVM Report 2020-0083. National Institute for Public Health and the Environment. <https://www.rivm.nl/bibliotheek/rapporten/2020-0083.pdf>

8. Shkemi, B., & Huppertz, T. (2021). Calcium Absorption from Food Products: Food Matrix Effects. *Nutrients*, 14(1), 180. <https://doi.org/10.3390/nu14010180>
9. Boudebouz, A., Boudalia, S., Bousbia, A., Habila, S., Boussadia, M. I., & Gueroui, Y. (2021). Heavy metals levels in raw cow milk and health risk assessment across the globe: A systematic review. *Science of The Total Environment*, 751, 141830. <https://doi.org/10.1016/j.scitotenv.2020.141830>
10. Rafiq, A., Shah, M. H., Mohany, M., Tahir, A. A., Elsadek, M. F., Qayyum, M. A., & Abbasi, A. M. (2022). Evaluation of Potentially Toxic Trace Metals and Associated Health Risk Assessment in Buffalo Milk. *International Journal of Environmental Research and Public Health*, 19(22), 14678. <https://doi.org/10.3390/ijerph192214678>
11. Ribeiro Sant'Ana, M. A., de Carvalho, T. C., & da Silva, I. F. (2021). Concentration of heavy metals in UHT dairy milk available in the markets of São Luís, Brazil, and potential health risk to children. *Food Chemistry*, 346, 128961. <https://doi.org/10.1016/j.foodchem.2020.128961>
12. European Commission. (2023). Regulation (EU) 2023/915 of 25 April 2023 on maximum levels of certain contaminants in foodstuffs. In *Official Journal of the European Union*, L 119, 5 May 2023, pp. 103–157. Publications Office of the European Union.
13. Mititelu, M., Neacșu, S. M., Busnatu, Ștefan S., Scafa-Udriște, A., Andronic, O., Lăcraru, A.-E., Ioniță-Mîndrican, C.-B., Lupuliasa, D., Negrei, C., & Olteanu, G. (2025). Assessing Heavy Metal Contamination in Food: Implications for Human Health and Environmental Safety. *Toxics*, 13(5), 333. <https://doi.org/10.3390/toxics13050333>
14. Bal-Prylypko, L., Berezina, L., Stepasyuk, L., Cherednichenko, O., & Lialyk, A. (2023). Developing dairy farming and improving product quality. *Scientific Horizons*, 27(1), 140–151. <https://doi.org/10.48077/scihor1.2024.140>
15. Peshuk, L. V., Kudryk, N. A., & Prykhodko, D. Y. (2025). Trends in the development of craft cheese production – Integration into the sustainable food system. In *Journal of Chemistry and Technologies*, 33(3), 714–727. <https://doi.org/10.15421/jchemtech.v33i3.328752>
16. Čapla, J., Zajác, P., Čurlej, J., Benešová, L., Jakabová, S., & Hleba, L. (2024). Authenticity Analysis of 100% Sheep's Bryndza from Selected Establishments in the Slovak Republic. *Journal of Microbiology, Biotechnology and Food Sciences*, 13(6), e10920. <https://doi.org/10.55251/jmbfs.10920>
17. Tarapoulouzi, M., Logan, N., Hardy, M., Montgomery, H., Haughey, S. A., Elliott, C. T., & Theocharis, C. R. (2024). A Pre-Trial Study to Identify Species of Origin in Halloumi Cheese Utilising Chemometrics with Near-Infrared and Hyperspectral Imaging Technologies. *Analytica*, 5(1), 17–27. <https://doi.org/10.3390/analytica5010002>
18. Rocha, L. S., Ramos, G. L. P. A., Rocha, R. S., Braz, B. F., Santelli, R. E., Esmerino, E. A., Freitas, M. Q., Mársico, E. T., Bragotto, A. P. A., Quitério, S. L., & Cruz, A. G. (2023). Heavy metals and health risk assessment of Brazilian artisanal cheeses. *Food Research International*, 174, 113659. <https://doi.org/10.1016/j.foodres.2023.113659>
19. Davydovych, V., Shevchenko, L., Brovenko, T., Nesterenko, N., Altanova, A., Umanets, R., Rudyk, Y., & Kovalenko, N. (2025). Microbiological changes in craft hard cheeses from raw goat milk during ripening with the use of mites *Acarus siro*. *Scifood*, 19, 176–191. <https://doi.org/10.5219/scifood.26>
20. Zajác, P., Čapla, J., Čurlej, J., Tkáčová, J., Partika, A., & Benešová, L. (2025). Composition profile of traditional Slovak ewe lump cheese. *Journal of Dairy Science*, 108(3), 2227–2242. <https://doi.org/10.3168/jds.2024-25809>
21. Zaritskyi, R., Zhuk, Y., Dreval, D., Kovpak, V., Masalovych, Y., Cheverda, I., Derkach, I., & Savchuk, T. (2024). Prevalence and sensitivity of contagious and environmental cow mastitis-causing pathogens to antibiotics in Ukrainian farms. *Potravinárstvo Slovak Journal of Food Sciences*, 18, 547–569. <https://doi.org/10.5219/1963>
22. Oliynyk, V., Zacharenko, M., Shevchenko, L., Mykhalska, V., Poliakovskiy, V., Slobodyanyuk, N., Ivaniuta, A., Pylypchuk, O., Omelian, A., & Gruntkovskiy, M. (2025). Evaluation of metabolic status in Holstein cow under short-term cold stress. *Online Journal of Animal and Feed Research*. <https://doi.org/10.51227/ojafr.2025.8>
23. Santarcangelo, C., Baldi, A., Ciampaglia, R., Dacrema, M., Di Minno, A., Pizzamiglio, V., Tenore, G. C., & Daglia, M. (2022). Long-Aged Parmigiano Reggiano PDO: Trace Element Determination Targeted to Health. *Foods*, 11(2), 172. <https://doi.org/10.3390/foods11020172>
24. Zajác, P., Čurlej, J., Čapla, J., Benešová, L., & Jakabová, S. (2023). Composition of Ewe's Lump cheese during the production season. *Cogent Food & Agriculture*, 9(1). <https://doi.org/10.1080/23311932.2023.2243105>

25. Sadvari, V. Y., Shevchenko, L. V., Slobodyanyuk, N. M., Tupitska, O. M., Gruntkovskiy, M. S., & Furman, S. V. (2024). Microbiome of craft hard cheeses from raw goat milk during ripening. *Regulatory Mechanisms in Biosystems*, 15(3), 483–489. <https://doi.org/10.15421/022468>
26. Iakubchak, O., Martynenko, O., Taran, T., Pylypchuk, O., Naumenko, T., Tverezovska, N., Menchynska, A., & Stetsyuk, I. (2024). Analysis of the hard rennet cheese microbiota at different stages of the technological process. *Potravinarstvo Slovak Journal of Food Sciences*, 18, 899–918. <https://doi.org/10.5219/2011>
27. Deshwal, G. K., Gómez-Mascaraque, L. G., Felon, M., & Huppertz, T. (2023). Determination of Minerals in Soft and Hard Cheese Varieties by ICP-OES: A Comparison of Digestion Methods. *Molecules*, 28(10), 3988. <https://doi.org/10.3390/molecules28103988>
28. Manuelian, C. L., Currò, S., Penasa, M., Cassandro, M., & De Marchi, M. (2017). Characterization of major and trace minerals, fatty acid composition, and cholesterol content of Protected Designation of Origin cheeses. *Journal of Dairy Science*, 100(5), 3384–3395. <https://doi.org/10.3168/jds.2016-12059>
29. Gaucheron, F. (2011). Milk and Dairy Products: A Unique Micronutrient Combination. *Journal of the American College of Nutrition*, 30(sup5), 400S–409S. <https://doi.org/10.1080/07315724.2011.10719983>
30. Davydovych, V., Shevchenko, L., Shulyak, S., Slobodyanyuk, N., Nedashkivskiy, V., Tomchuk, V., Slyva, Y., Nesterenko, N., Sydorenko, O., & Ivaniuta, A. (2025). The influence of ripening time on the physicochemical characteristics of craft hard goat cheeses. *Online Journal of Animal and Feed Research*. <https://doi.org/10.51227/ojafir.2025.30>
31. Torfadóttir, J. E., & Uusi-Rasi, K. (2023). Calcium – a scoping review for Nordic Nutrition Recommendations 2023. *Food & Nutrition Research*, 67. <https://doi.org/10.29219/fnr.v67.10303>
32. Sadvari, V. Y., Shevchenko, L. V., Slobodyanyuk, N. M., Furman, S. V., Lisohurska, D. V., & Lisohurska, O. V. (2024). Chemical composition of craft hard cheeses from raw goat milk during the ripening process. In *Regulatory Mechanisms in Biosystems*, 15(4), 666–673. <https://doi.org/10.15421/022496>
33. Drašler, V., Kralj Cigić, I., Polak, T., Marolt, G., Imperl, J., Čanžek Majhenič, A., & Cigić, B. (2025). Spatial Distribution of Minerals and Selected Bioactive Compounds in White Mold-Ripened and Blue-Veined Cheeses. *Molecules*, 30(18), 3819. <https://doi.org/10.3390/molecules30183819>
34. Manzi, P., Di Costanzo, M. G., & Ritota, M. (2021). Content and Nutritional Evaluation of Zinc in PDO and Traditional Italian Cheeses. *Molecules*, 26(20), 6300. <https://doi.org/10.3390/molecules26206300>
35. Souto, M. R. S., Pimenta, A. M., Catarino, R. I. L., Leal, M. F. C., & Simões, E. T. R. (2025). Heavy Metals in Milk and Dairy Products: Safety and Analysis. *Pollutants*, 5(3), 29. <https://doi.org/10.3390/pollutants5030029>
36. Krivohlavek, A., Palac Bešlić, I., Jurak, G., Gavran, M., Mandić Andačić, I., Ivešić, M., Šikić, S., Vitale, K., Štefančić, M., Žuntar, I., Oštarić, F., & Mikulec, N. (2024). Heavy Metals and Pesticide Residues in Small Farm Cheese Production in Croatia—Challenge between Quality and Quantity. *Sustainability*, 16(4), 1356. <https://doi.org/10.3390/su16041356>
37. Favretto, L. G. (1990). Investigation of trace element content of cheese. *Food Additives and Contaminants*, 7(3), 425–432. <https://doi.org/10.1080/02652039009373905>
38. Suturović, Z., Kravić, S., Milanović, S., Đurović, A., & Brezo, T. (2014). Determination of heavy metals in milk and fermented milk products by potentiometric stripping analysis with constant inverse current in the analytical step. *Food Chemistry*, 155, 120–125. <https://doi.org/10.1016/j.foodchem.2014.01.030>
39. Vural, A., Narin, I., Erkan, M. E., & Soylak, M. (2008). Trace metal levels and some chemical parameters in herby cheese collected from south eastern Anatolia–Turkey. In *Environmental Monitoring and Assessment*, 139(1), pp. 27–33. <https://doi.org/10.1007/s10661-007-9811-3>
40. Barone, G., Dambrosio, A., Storelli, A., Busco, A., Ioanna, F., Quaglia, N. C., Giacomini-Stuffler, R., & Storelli, M. M. (2018). Traditional Italian cheeses: Trace element levels and estimation of dietary intake. *Journal of Food Composition and Analysis*, 66, 205–211. <https://doi.org/10.1016/j.jfca.2017.12.025>
41. Altınsoy, C., Taban, G., Tajdar-oranj, B., Sadighara, P., & Basaran, B. (2025). Occurrence of potentially toxic metals in Turkish cheese with dietary intake and health risk assessment. *Scientific Reports*, 15(1). <https://doi.org/10.1038/s41598-025-18813-1>
42. Erol, S., & Ürkek, B. (2025). Safety and Nutritional Profile of Traditional Turkish Cheeses: A Comprehensive Study on Their Mineral Content, Heavy Metal Contamination, and Health Risks of Aho, Golot, and Telli. *Food Science & Nutrition*, 13(7). <https://doi.org/10.1002/fsn3.70560>
43. Anguebes-Franseschi, F., Abatal, M., Alejandra Ucán, C., Ruiz Marín, A., Tamayo-Ordoñez, F., Canedo-López, Y., Perez-Reda, L., & Damás-Damas, S. (2023). Determination of the Concentration of Heavy Metals in Artisanal Cheeses Produced in the Mexican States of Tabasco and Chiapas. *Molecules*, 28(23), 7907. <https://doi.org/10.3390/molecules28237907>

44. European Commission. (2006). Regulation No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. In Official Journal of the European Union, L 364, 20.12.2006, 5. Publications Office of the European Union. <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX%3A32021R1323>
45. European Food Safety Authority (EFSA). (2009). Cadmium in food - Scientific opinion of the Panel on Contaminants in the Food Chain [JB]. EFSA Journal, 7(3). <https://doi.org/10.2903/j.efsa.2009.980>
46. EFSA Panel on Contaminants in the Food Chain (CONTAM). (2014). Scientific Opinion on the risks to public health related to the presence of chromium in food and drinking water [JB]. EFSA Journal, 12(3). <https://doi.org/10.2903/j.efsa.2014.3595>
47. EFSA Panel on Contaminants in the Food Chain (CONTAM), Schrenk, D., Bignami, M., Bodin, L., Chipman, J. K., del Mazo, J., Grasl-Kraupp, B., Hogstrand, C., Hoogenboom, L. (Ron), Leblanc, J., Nebbia, C. S., Ntzani, E., Petersen, A., Sand, S., Schwerdtle, T., Vleminckx, C., Wallace, H., Guérin, T., Massanyi, P., ... Nielsen, E. (2020). Update of the risk assessment of nickel in food and drinking water [JB]. EFSA Journal, 18(11). <https://doi.org/10.2903/j.efsa.2020.6268>
48. EFSA Panel on Contaminants in the Food Chain (CONTAM). (2010). Scientific Opinion on Lead in Food [JB]. EFSA Journal, 8(4). <https://doi.org/10.2903/j.efsa.2010.1570>
49. DSTU 6003:2008. (2009). Hard cheese. General specifications. In National Standard of Ukraine. Derzhspozhyvstandart of Ukraine. (National Standard of Ukraine). [https://zakon.isu.net.ua/sites/default/files/normdocs/dstu\\_6003\\_2008.pdf](https://zakon.isu.net.ua/sites/default/files/normdocs/dstu_6003_2008.pdf)
50. D’Incecco, P., Limbo, S., Hogenboom, J., Rosi, V., Gobbi, S., & Pellegrino, L. (2020). Impact of Extending Hard-Cheese Ripening: A Multiparameter Characterization of Parmigiano Reggiano Cheese Ripened up to 50 Months. Foods, 9(3), 268. <https://doi.org/10.3390/foods9030268>

#### Funds:

This work was not supported by any grant.

#### Acknowledgments:

-

#### Competing Interests:

The authors declare no conflict of interest

#### Ethical Statement:

This article does not contain any studies that would require an ethical statement.

#### AI Statement:

AI tools were not used.

#### Contact Address:

##### Viktor Davydovych

Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Veterinary Medicine, Department of Animal and Food Hygiene named after Professor A.K. Skorokhodko, Vystavkova Str., 16, 03041, Kyiv, Ukraine

Tel.: +38(098)-010-03-78

E-mail: [davidovih@ukr.net](mailto:davidovih@ukr.net)

ORCID: <http://orcid.org/0000-0002-2864-9018>

Author contribution: Project administration.

##### Larysa Shevchenko

Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Veterinary Medicine, Department of Animal and Food Hygiene named after Professor A.K. Skorokhodko, Vystavkova Str., 16, 03041, Kyiv, Ukraine

Tel.: +38(050)193-10-29

E-mail: [shevchenko\\_laris@ukr.net](mailto:shevchenko_laris@ukr.net)

ORCID: <http://orcid.org/0000-0001-7472-4325>

Author contribution: Writing – review & editing.

**Nataliia Slobodianiuk**

Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Food Sciences, Nutrition and Quality Management Department of technology of meat, fish and marine products, Vystavkova Str., 16, 03041, Kyiv, Ukraine  
Tel.: +38(098)2768508  
E-mail: [slob2210@ukr.net](mailto:slob2210@ukr.net)  
ORCID: <https://orcid.org/0000-0002-3646-1226>  
Author contribution: Project administration.

**Nataliia Holembovska**

Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Food Sciences, Nutrition and Quality Management, Department of technology of meat, fish and marine products, Vystavkova Str., 16, Kyiv, 03041, Ukraine  
Tel.: +38(096)206-62-76  
E-mail: [natashagolembovska@gmail.com](mailto:natashagolembovska@gmail.com)  
ORCID: <https://orcid.org/0000-0001-8159-4020>  
Author contribution: Project administration.

**Oksana Pylypchuk**

Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Food Sciences, Nutrition and Quality Management, Department of Meat, Fish, and Seafood Technology, Vystavkova Str., 16, 03041, Kyiv, Ukraine,  
Tel.: +38(096) 961-20-83  
E-mail: [pilipchuk\\_os@ukr.net](mailto:pilipchuk_os@ukr.net)  
ORCID: <https://orcid.org/0000-0002-2757-6232>  
Author contribution: Project administration.

**Vasyl Shynkaruk**

Affiliation: National University of Life and Environmental Sciences of Ukraine, Department of philosophy and international communication, Heroiv Oborony str., 15, Kyiv, 03041, Ukraine  
Tel.: +380 (97)048-23-32  
E-mail: [vashyn@nubip.edu.ua](mailto:vashyn@nubip.edu.ua)  
ORCID <https://orcid.org/0000-0001-8589-4995>  
Author contribution: Project administration.

**Alona Altanova**

Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Food Sciences, Nutrition and Quality Management, Department of Public Health and Nutrition, Vystavkova, Str., 16, 03040, Kyiv, Ukraine  
Tel.: +38(050)812-23-51  
E-mail: [al.altanova@gmail.com](mailto:al.altanova@gmail.com)  
ORCID: <https://orcid.org/0000-0002-2783-4932>  
Author contribution: Project administration.

**Mykola Gruntkovskiy**

Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Animal Technology, Heroiv Oborony str., 15, Kyiv, 03041, Ukraine,  
Tel.: +38(098)769-10-99,  
E-mail: [m-gruntkovskiy@nubip.edu.ua](mailto:m-gruntkovskiy@nubip.edu.ua)  
ORCID <https://orcid.org/0000-0002-6969-2987>  
Author contribution: Project administration.

Corresponding author: **Oksana Pylypchuk**

**Copyright notice:**

© 2026 The Author(s). Published by HACCP Consulting, Slovakia, European Union, on *Scifood* (<https://scifood.eu>), the official website of the journal. *Scifood* is owned and operated by HACCP Consulting s.r.o. (<https://www.haccp.sk>). This article is published as **Open Access** under the **Creative Commons Attribution–NonCommercial–NoDerivatives 4.0 International License** <https://creativecommons.org/licenses/by-nc-nd/4.0/> (CC BY-NC-ND 4.0). This license permits non-commercial use, sharing, distribution, and reproduction in any medium or format, provided that appropriate credit is given to the author(s) and the original publication, a link to the license is provided, and the work is not modified, adapted, or transformed.