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THE INFLUENCE OF RIPENING TIME ON THE PHYSICOCHEMICAL CHARACTERISTICS OF CRAFT HARD GOAT CHEESES

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ABSTRACT: **The unique taste characteristics of craft hard cheeses made from raw goat milk, ripened using mites *Acarus siro* L., have contributed to increasing consumer demand enable the assessment of their quality and authenticity. In this study, 15 heads of Alpine and Yoghurt cheeses each weighing 4.5-5.0 kg were produced from raw goat milk and allowed to ripen for 12 and 18 months, respectively. Both cheeses were ripened with natural surface colonization by the mites *Acarus siro* L. It was found that the moisture content of Alpine cheese decreased from 43.31 on day 7 to 28.99% at 12 months of age, and the moisture content of Yoghurt cheese decreased from 46.90% on day 7 to 29.99% at 18 months. Moisture loss in both cheeses was strongly dependent on ripening time. The protein content in craft hard cheeses increased with age: from 21.45% to 28.68% in Alpine cheese and from 20.52% to 29.52% in Yoghurt cheese. Corresponding to the increase in dry matter content, fat content also increased in both varieties: from 24.45% to 31.50% in Alpine cheese and from 22.06% to 29.91% in Yoghurt cheese. A characteristic feature of both cheeses was the formation of holes, the size and distribution of varied with ripening duration. The hardness of Alpine and Yoghurt cheeses decreased with age, while the fracturability increased, reaching a minimum in the oldest cheeses, a change closely related to moisture loss. The rind of old-ripened Alpine and Yoghurt cheeses exhibited an amber color of varying intensity, with small verrucae due to the activity of the mite *Acarus siro* L. The observed changes in the physicochemical characteristics of young, mature, and old-ripened artisanal cheeses made from raw goat milk can serve as criteria for assessing their quality, age, and authenticity. Production of such cheeses contributes to diversifying the product range and enhancing the market competitiveness of premium goat cheeses.**

Keywords: Alpine cheese, Dry matter, Mite *Acarus siro* L, Rind, Yoghurt cheese.

INTRODUCTION

Cheese is a food product with a technology history spanning over 8,000 years. The raw material for cheese production is milk, sourced from various mammals. Milk-processing technologies continuously refined are crucial for developing new cheese varieties. By manipulating ripening parameters time, temperature, and humidity and incorporating additives such as fruits, nuts, or spices, producers achieve an extraordinary diversity of cheeses with distinctive textures, flavors, and aromas (Zhang et al., 2021). The growing emphasis on healthy eating has driven the production of raw-milk cheeses that undergo minimal or no processing. This primarily concerns the production of craft hard cheeses small ruminants, especially goats. Such cheeses are not only rich in macro- and micronutrients and bioactive compounds, but also harbor beneficial lactic acid bacteria that may support human health (Hosken et al., 2023). Recent studies report rising production and consumption of hard and semi-hard cheeses across Europe, trends that correlate with increased life expectancy and reduced cardiovascular disease risk in European populations (Nájera et al., 2021).

In the European Union, over 90% of cheese production is derived from cow's milk, with sheep and goat cheeses accounting for only 2%. Although Ukraine is not yet a major global cheese producer or exporter, it has substantial potential to expand goat-milk cheese varieties via smallholder farmers, driven by rising demand for mature and long-ripened cheeses (Mureșan et al., 2021). Despite representing a small proportion of global hard and semi-hard cheese production, goat cheeses are considered premium varieties thanks to their distinctive flavors and hold a place of pride on cheeseboards. Craft raw goat-milk cheeses produced in small batches and characterized by superior sensory qualities

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compared to industrial cheeses are particularly prized. These attributes are attributed to goat cheese's high fat content and elevated levels of free amino acids. These attributes are attributed to goat cheese's high fat content and elevated levels of free amino acids.

The chemical composition of cheese depends not only on the species and blend of milk but also on seasonal factors, herd health (Oliynyk et al., 2024), the initial milk composition (Mylostyvyi et al., 2023), and the specific production and ripening technologies. The structure, appearance, and internal texture of cheese serve as key quality criteria and influence consumer appeal. The rind color, slice shape, and presence, size, and distribution of holes provide visual quality cues that consumers use before tasting. The physicochemical changes in hard goat cheese are strongly influenced by ripening duration and environmental conditions. Ripening transforms fresh curd into cheese with defined appearance, texture, aroma, and flavor profiles. The unique sensory profile of raw goat-milk cheese arises from interactions among microbial communities and arthropods—particularly rind-forming mites—and the balance of chemical constituents. The physicochemical properties of hard cheese serve as indicators of quality, safety, maturity, and authenticity, reflecting the extent of lipolysis, proteolysis, and glycolysis during ripening (Álvarez and Fresno, 2021).

With each passing year, new consumers increasingly prefer cheeses made from raw goat milk due to their more pronounced and piquant taste compared to cheeses made using industrial pasteurization of milk. The main disadvantage of milk pasteurization is the inactivation of beneficial microorganisms together with pathogenic and undesirable ones. This leads to reduced activity of proteases and lipases, which are essential for the unique taste and aroma of cheeses (Sakaridis et al., 2022). In addition to the deteriorated sensory characteristics, pasteurisation affects milk quality, as evidenced by Canestrato Pugliese PDO cheese. Despite the stability of the chemical composition, sensory properties of this cheese were significantly inferior those of raw milk (Natrella et al., 2023). These data highlight the important role of the microbiota indigenous to a given region and responsible for) lipolysis and proteolysis, generating key aromatic compounds (Shulga et al., 2023). Consequently, the use of autochthonous rennet is explored to create a microbial consortium closely resembling that of) raw milk (Vera-Santander et al., 2024).

To date, researchers mostly continue to debate the safety of using of raw versus pasteurized milk in cheese-making. Proponents emphasize compliance with stringent sanitary requirements during milk production and processing, coupled with rigorous hygienic practices during ripening to ensure product safety. Despite recent growing interest in investigating the characteristics of craft cheeses produced from raw goat milk, their physicochemical composition has been inadequately characterized owing to the continuously expanding product range. Therefore, this study aims to determine the physicochemical characteristics of Alpine and Yoghurt craft hard cheeses produced from raw goat milk as a function of ripening period. This approach will enable the establishment of reliable criteria for age, quality, and authenticity.

MATERIALS AND METHODS

Animals

Goat milk was used in the study.Milk was sourced from Anglo-Nubian goats at Eco Farm Zhuravka in the Kyiv region.

Experimental Design

In this study, two batches of Alpine and Yoghurt craft hard cheeses produced from raw goat milk were prepared according to the scheme described by Davydovych et al. (2025). The study period spanned May 2023 to January 2025. Samples were chosen based on age: young (7 days), mature (6 months) and aged (12 months for Alpine cheese and 18 months for Yoghurt cheese).

Sampling

The study used 15 heads of Alpiyskiy cheese and 15 heads of Yogurtovy cheese. For analysis, 5 heads of Alpiyskiy cheese with a ripening period of 7 days, 6 months and 12 months were selected, as well as 5 heads of Cheese Yogurt aged 7 days, 6 months and 18 months. Average samples of cheese weighing at least 200 g were taken from each head, packed in vacuum packaging and delivered chilled to the analytical laboratory.

Sample Analysis

Cheese chemical parameters s was analyzed at the State Scientific and Research Institute for Laboratory Diagnostics and Veterinary and Sanitary Expertise (SSRILDVSE), in Kyiv, Ukraine. The SSRILDVSE testing center is accredited by the National Accreditation Agency of Ukraine under DSTU EN ISO/IEC 17025:201 standards. The moisture, dry matter, ash, protein, and fat contents of the goat-milk hard cheeses were determined as follows. Moisture content was measured by gravimetric analysis, drying samples in a VENTICELL oven (BMT, Czech Republic). Dry matter was calculated by difference. Nitrogen content was determined by the Kjeldahl method: samples were digested in an automatic mineralizer (Velp Scientifica DKL 12, Italy), distilled using a semi-automatic steam distiller (UDK 139, Velp Scientifica, Italy), and distilled ammonia quantified with an automatic Kjeldahl steam distillation unit (DKL 12, Velp Scientifica, Italy). Protein content was calculated using the appropriate nitrogen conversion factor. Ash content was assessed by incineration in a SNOL muffle furnace (Utenoselektrotechnika, Germany). Fat content was determined by acid hydrolysis (concentrated sulfuric acid and isoamyl alcohol), followed by centrifugation (Nova Safety centrifuge, Funke-Gerber, Germany) and measurement of the fat layer in a graduated butyrometer. Cheese hardness was expressed as the percentage ratio of moisture weight to the weight difference between the total sample and its fat portion. To identify the mite *Acarus siro*, the rind cuts of Alpine and Yoghurt cheeses (aged > 6 months and 3–4 mm thick) were taken (Mullen and OConnor, 2019), placed on a glass slide and examined under liquid petrolatum (PJSC “Pharmaceutical Factory “Viola”, Ukraine). Observations were performed with a Micromed Evolution ES-4140 microscope equipped with a camera adapter (Ningbo Shenghen Optics & Electronics Co., Ltd., Bulgaria).

Statistical analysis

Data were analyzed by one-way ANOVA. Changes in physicochemical parameters of Alpine and Yoghurt hard cheeses as a function of ripening period were evaluated by correlation and regression analyses.) Analyses were conducted using Microsoft Excel 2016 and XLSTAT (Addinsoft, Paris- 2017). Results are presented as mean ± SD. Within each cheese type, differences were considered significant at P < 0.05 using Tukey’s test with Bonferroni correction.

RESULTS AND DISCUSSION

The ripening of Alpine hard cheese was characterized by the greatest moisture loss at the 6th month, amounting to 12.47% compared to the young cheese aged 7 days. Moisture content decreased from 43.31% to 30.84% between the 7th day to 6 months. From the 6th to the 12th month of ripening, Alpine cheese showed minimal further moisture loss, with its moisture content stabilizing (Table 1). The proportions of the major dry-matter components of Alpine cheese varied in response to moisture loss. Specifically, fat content increased to 29.99% in mature cheese (6 months) and to 31.50% in aged cheese (12 months), compared to young cheese (7 days). Protein content exhibited similar trends. As expected, increased dry-matter content was comprised by higher ash content до 4.85% at 6 months and до 4.49% at 12 months relative to cheese aged 7 days. A strong inverse correlation relationship was observed between moisture content (r = -0.904 ± 0.081, P < 0.001) and hardness (r = -0.893 ± 0.085, P < 0.001), with ripening period, while fat content displayed a strong positive correlation (r = -0.909 ± 0.078, P < 0.001). In all cases, the data were best fitted by a second-degree polynomial regression curve (Figure 1).

Table 1 - Chemical analysis of Alpine craft hard cheese, x ± SD, %

Parameter \ Ripening period of cheese	7th days	6 months	12 months
Moisture	43.31 ± 1.22[a]	30.84 ± 0.59[b]	28.99 ± 0.66[b]
Fat	24.45 ± 0.86[b]	29.99 ± 0.54[a]	31.50 ± 1.27[a]
Protein	21.45 ± 0.61[b]	28.90 ± 0.35[a]	28.67 ± 0.34[a]
Ash	3.19 ± 0.13[b]	4.85 ± 0.22[a]	4.49 ± 0.25[a]

*Note: Different letters of superscript indicate the probable differences between the values within the same table row (P < 0.05) as determined by Tukey test with Bonferroni correction.

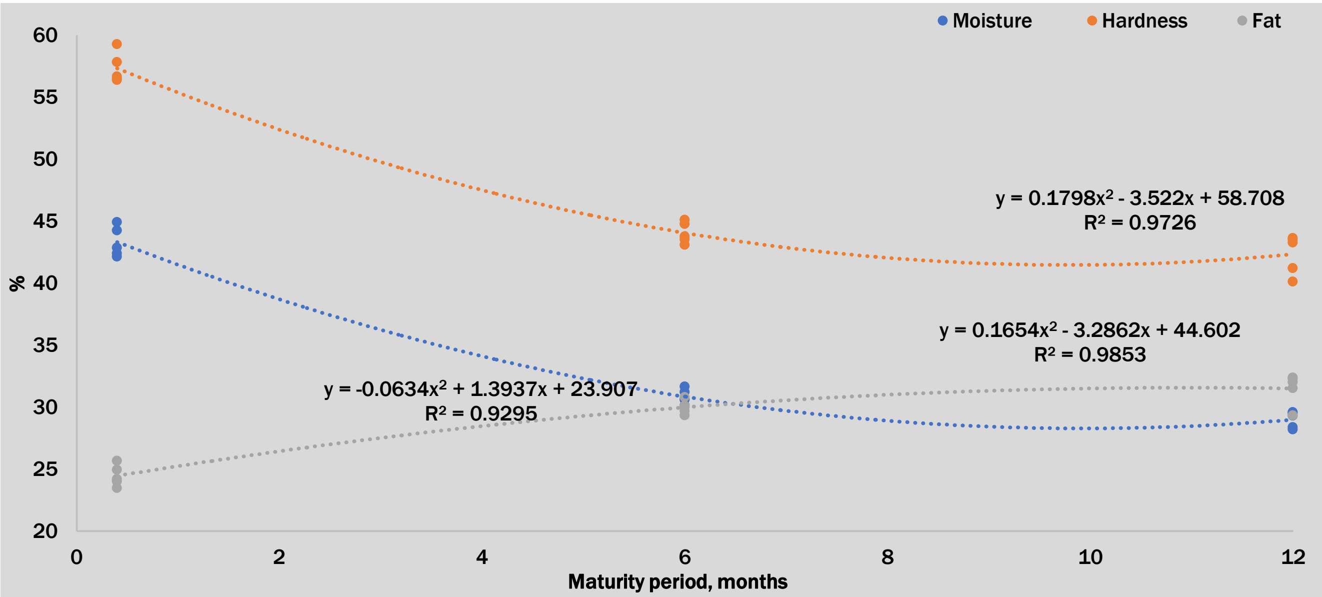

Figure 1 - Relationship between moisture, fat, and hardness and the ripening period of Alpine cheese (n = 15).

Fat content in dry matter remained constant with age, whereas protein content increased to 41.80% at 6 months and by to 40.39% at 12 months, respectively, compared to young cheese (Table 2). This, in turn, contributed to a reduction of the fat-to-protein ratio by 0.11 points at 6 months. Cheese hardness decreased with age falling to 44.05 units at 6 months and to 42.34 units at 12 months. Young Alpine cheese (7 days) exhibited a milk-colored rind indistinguishable from paste (Figure 2 a, b). The cheese interior was characterized by a homogeneous, plastic paste with isolated, small, rounded eyes. It was easy to slice and exhibited a rubbery consistency. At 6 months, the Alpine cheese rind displayed a golden hue, was well developed, and contrasted with the paste. The paste was plastic and homogeneous, containing small, rounded, and irregularly shaped eyes. Some eyes coalesced, particularly in the cheese core) (Figure 2 c, d). At 12 months, the rind was well formed, dark amber, layered, and exhibited localized *A. siro* damage, creating contrast with the paste. The paste remained homogeneous yet slightly brittle, with rounded and irregular eyes, some of which had merged. Small dark spots near the rind (Figure 2 e, f) corresponded to residual *A. siro* activity.

Ripening of Yoghurt hard cheese exhibited characteristics distinct from that Alpine cheese. Moisture content of Yoghurt cheese was strongly inversely correlated with ripening period dependence ($r = -0.935 \pm 0.067$, $P < 0.001$), while ash content showed a strong positive correlation ($r = -0.958 \pm 0.054$, $P < 0.001$). Regression analysis indicated that moisture content varied with age according to a second-degree polynomial, whereas ash content increased linearly throughout ripening (Figure 3).

At the same time, the intensity of moisture loss in this cheese from the 7th day to the 6th month of ripening decreased from 46.91% to 36.54%, while by the 18th month – to 29.93%. Against the background of an increase in the dry matter content, the fat content in Yogurtovy cheese significantly increased from 22.06% to 30.83% by the 6th month and to 29.91% by the 18th month of ripening. Protein concentration exhibited a similar trend during ripening (Table 3).

Fat and protein contents in Yoghurt cheese dry matter peaked at 6 months, whereas levels in young and aged cheeses were significantly lower (Table 4). However, these fluctuations did not alter the fat-to-protein ratio throughout ripening. A strong inverse linear correlation was observed between Yoghurt cheese hardness and ripening period ($r = -0.974 \pm 0.043$, $P < 0.001$). Regression analysis likewise demonstrated that protein and fat contents in dry matter vary with ripening period, fitting a second-degree polynomial (Figure 4). On day 7 of ripening, Yoghurt cheese had a well-formed, continuous rind indistinguishable from the paste. The slice exhibited a rubbery texture with medium and small holes distributed across the surface (Figure 5 a, b). At 6 months, the Yoghurt cheese rind was light amber and contrasted with the paste. The paste contained small and medium irregularly shaped holes throughout, some of which had coalesced in the core. At this stage, the paste was plastic yet slightly brittle (Figure 5 c, d). At 18 months, Yoghurt cheese met the criteria for aged cheese, featuring a hard amber rind that contrasted with the paste. The rind bore layered damage and small lesions attributable to *A. siro* activity. This cheese was difficult to slice, exhibiting a brittle texture with randomly distributed medium-sized holes (Figure 5 e, f).

Table 2 - Physicochemical analysis of dry matter of Alpine craft hard cheese in ripening process, x ± SD, %

Parameter \ Ripening period of cheese	7 days	6 months	12 months
Fat, %	43.14 ± 1.06	43.36 ± 0.81	44.37 ± 2.07
Protein, %	37.87 ± 1.87^{b}	41.80 ± 0.70^{a}	40.39 ± 0.49^{a}
Fat-to-protein ratio, un.	1.14 ± 0.07^{a}	1.03 ± 0.02^{b}	1.11 ± 0.05^{ab}
Hardness, un.	57.33 ± 1.23^{a}	44.05 ± 0.85^{b}	42.34 ± 1.58^{b}

*Note: Different letters of superscript indicate the probable differences between the values within the same table row (P < 0.05) as determined by Tukey test with Bonferroni correction.

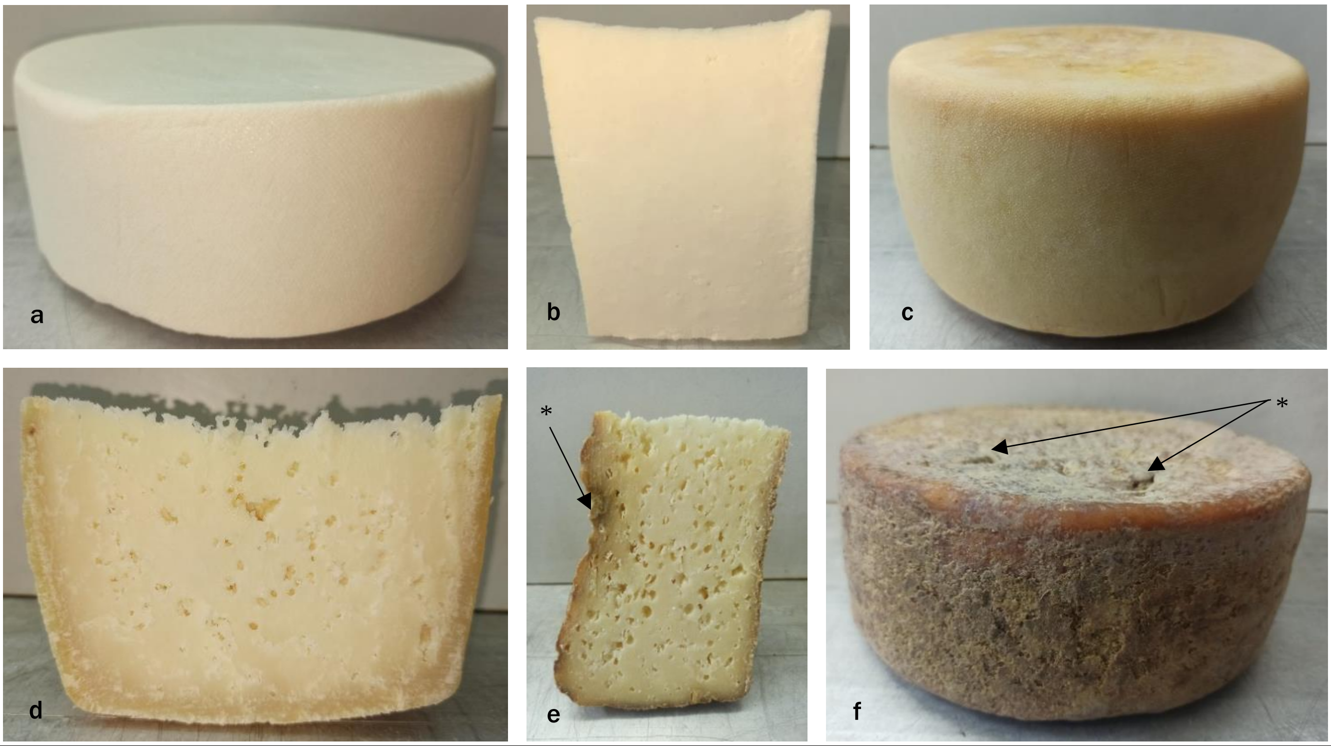

Figure 2 - Alpine cheese with ripening period of 7 days (a: head, b: slice); 6 months (c: head, d: slice); 12 months (e: head, f: slice); *: place of damage to cheese rind by mite.

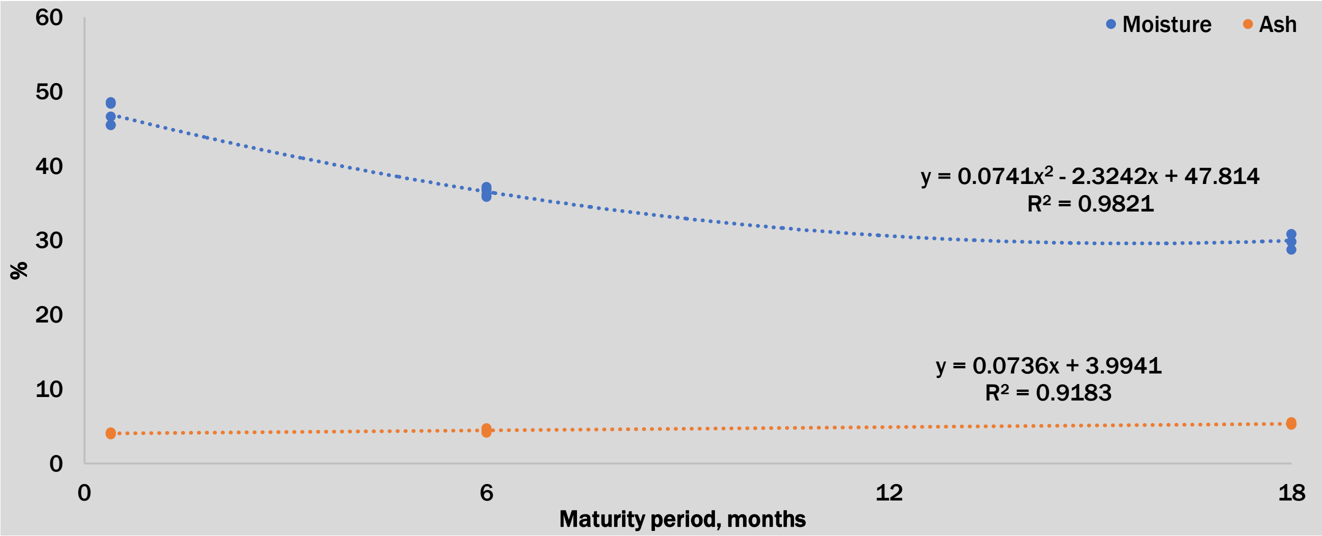

Figure 3 - Relationship between moisture and ash contents and ripening period of Yoghurt cheese (n = 15).

Table 3 - Chemical composition of Yoghurt craft hard cheese, x ± SD, %.

Parameter / Ripening period of cheese	7 days	6 months	12 months
Moisture	46.91 ± 1.53[a]	36.54 ± 0.54[b]	29.93 ± 0.87[c]
Fat	22.06 ± 0.18[b]	30.83 ± 0.92[a]	29.91 ± 0.81[a]
Protein	20.52 ± 0.53[b]	28.77 ± 0.43[a]	29.52 ± 0.23[a]
Ash	4.13 ± 0.17[c]	4.43 ± 0.09[b]	5.32 ± 0.13[a]

*Note: Different letters of superscript indicate the probable differences between the values within the same table row ($P < 0.05$) as determined by Tukey test with Bonferroni correction.

Table 4 - Physiochemical composition of dry matter of Yoghurt craft hard cheese during ripening period, x ± SD, %.

Parameter / Ripening period of cheese	7 days	6 months	12 months
Fat	41.56 ± 1.27[b]	48.58 ± 1.42[a]	42.71 ± 0.82[b]
Protein	38.65 ± 0.64[c]	45.34 ± 0.77[a]	42.17 ± 0.25[b]
Fat-to-protein-ratio	1.08 ± 0.03	1.07 ± 0.04	1.01 ± 0.02
Hardness	60.17 ± 1.95[a]	52.83 ± 0.96[b]	42.78 ± 0.94[c]

*Note: Different letters of superscript indicate the probable differences between the values within the same table row ($P < 0.05$) as determined by Tukey test with Bonferroni correction.

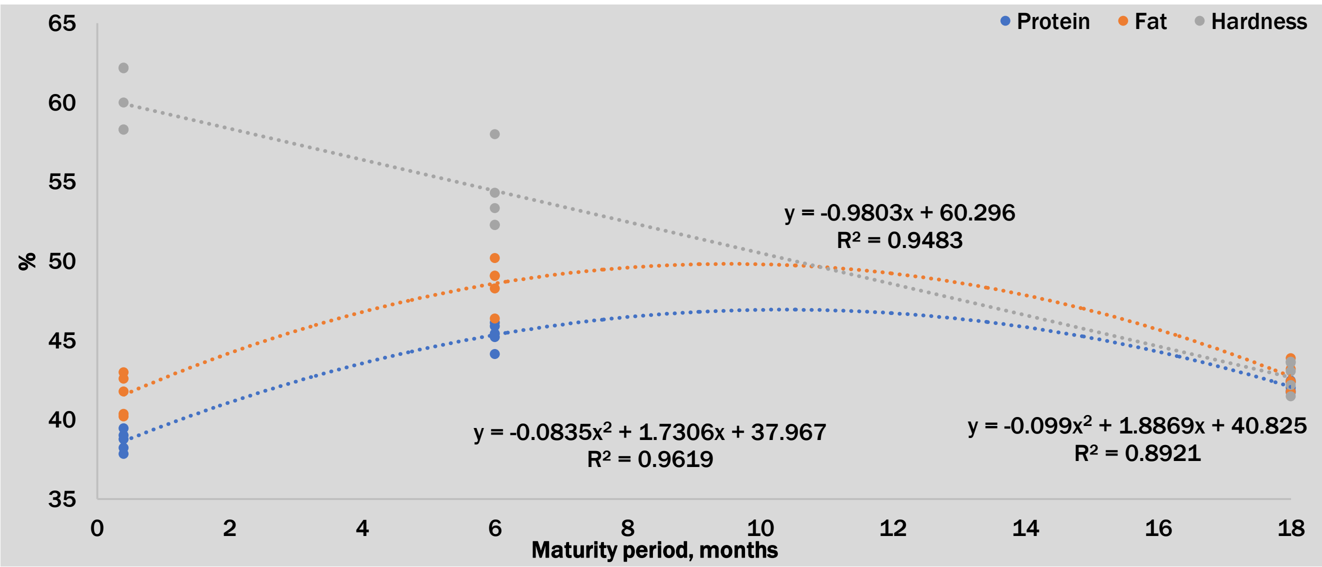

Figure 4 - Relationship between dry-matter protein and fat contents, and hardness, versus ripening period of Yoghurt cheese (n = 15).

Figure 5 - Yoghurt cheese with ripening period of 7 days (a: head, b: slice); 6 months (a: head, b: slice); 18 months (e: head, f: slice).

Moisture content of hard cheeses, including Alpine and Yoghurt, influences both yield and ripening suitability. According to standard classifications extra-hard cheese should have moisture content of 25-35%, hard - 35-45%, semi-hard - 45-50%, semi-soft - 42-55%, and soft - 55-80% (Zheng et al., 2021). Alpine cheese is hard at 7 days and extra-hard at 6–12 months, whereas Yoghurt cheese is semi-hard at 7 days, hard at 6 months, and extra-hard at 18 months. The results of this study are consistent with the previously obtained data on the chemical composition of Caciotta and Canestrato hard cheeses made from raw goat milk. Moisture-loss patterns vary with production technique and rind development. In Caciotta cheese made from raw goat milk, moisture content decreased from 44.4 to 25.1% over 24 months. Increased dry matter corresponded to rises in fat (27.0 to 36.5%), protein (23.8 to 33.2%), and ash (3.4 to 4.3%), accompanied by greater brittleness and reduced hardness (39.5%).

The highest moisture loss in Canestrato hard cheese occurred between months 6 and 12 (4.4%) (Sadvari et al., 2024a). The observed moisture-loss trends for Alpine and Yoghurt cheeses align with reports on traditional Chinese cheeses (23.2–59.2% moisture; Zhang et al., 2022) and Korycińskie semi-hard varieties, demonstrating dependence on ripening-room temperature and casein matrix water-holding capacity (Kliks et al., 2022; Tulyaganovich et al., 2022).

Ripening duration and conditions govern biochemical processes—glycolysis, lipolysis, and proteolysis—that generate the distinctive sensory profile of goat cheeses (Levak et al., 2023a). Cheese fat content modulates sensory richness, with the fat-to-protein ratio typically ranging from 0.70 to 1.15 (Lipkowitz et al., 2018). In both Alpine and Yoghurt cheeses, this ratio remained within the specified limits throughout ripening. Mineral content in Alpine and Yoghurt hard cheeses slightly increased with age, as indicated by ash content; however, this trend was not strictly linear and reflected concurrent rises in dry-matter levels. Production practices—particularly pasture-based feeding—also influence cheese mineral profiles. Artisanal cheeses exhibit mineral compositions comparable to those of organic varieties (de Oliveira Filho et al., 2022). Salt content is a key determinant of both mineral balance and flavor (Møller et al., 2013). Recently, hard cheese producers have extended ripening to produce premium ultra-hard cheeses for target markets (Levak et al., 2023b). This study also included Alpine and Yoghurt cheeses made from raw goat milk aged 12 and 18 months, respectively. Hard-cheese quality depends not only on milk composition but also on microbial species and abundance (Sadvari et al., 2024b; Iakubchak et al., 2024; Kukhtyn et al., 2025).

Microbial effects on sensory properties and structure are exemplified by rind formation in PDO Pecorino Siciliano, PDO Piacentinu Ennese, and Caciocavallo Palermitano cheeses (Settanni et al., 2021). Hard-cheese texture varies substantially with both type and age. Our observations of Alpine and Yoghurt cheeses align with findings for young and mature Kope cheeses (Esmaeilzadeh et al., 2021). In Kope cheese, initial rubbery consistency at day 7 transitions to increased hardness by day 187; proteolysis under acidic conditions gradually homogenizes texture by weakening the casein network. Aged cheeses exhibit increased hardness and brittleness from casein hydration, and weakened interparticle bonds enhance friability, accounting for the fragile structure of Alpine (12 months) and Yoghurt (18 months) cheeses. Texture is also influenced by production methods—especially pasteurization—and differences between industrial and artisanal technologies markedly affect cheese quality. For example, industrially produced Fiore Sardo PDO (sheep milk) exhibited greater paracasein hydration and water-to-protein proton ratio than artisanal counterparts. In our study, artisanal cheeses displayed more eyes on the slice surface than industrial samples (Anedda et al., 2021).

In Alpine cheese, eye formation intensified with maturity, with minimal coalescence. Conversely, Yoghurt cheese exhibited eye coalescence in the core at 6 months, while aged samples featured discrete medium-sized eyes within a dense matrix—likely due to elevated CO_2 partial pressure and softer paste in the core relative to the rind. Carbon dioxide generatedduring ripening initially dissolved in the cheese matrix influenced by microbial community composition (Munch et al., 2023). Within cheese, CO_2 is partly irreversibly absorbed into the paste and partly remains in the free phase (Lepilkina et al., 2021). Once saturation occurs, CO_2 diffuses to form eyes or escapes through the rind (Auer et al., 2021). Excessive CO_2 production and increased partial pressure can coalesce eyes, creating undesirable cracks or fissures (Lamichhane et al., 2021). Although extensive eye formation may compromise the market appearance of long-ripened cheeses like Emmental, Gouda, or Maasdam, they remain suitable for shredding, processing, or inclusion in other dishes (González et al., 2020). Similarly, these secondary uses may apply to craft Alpine and Yoghurt goat-milk cheeses; however, defects often arise from rind damage by *A. siro* rather than excessive eye formation. Rind development critically shapes internal texture and biochemical activity; in this study, cheeses were ripened uncoated.

A debate regarding the safety of arachnid-ripened cheeses, particularly those involving mites. It is believed that *Acarus siro*, the species most frequently associated with cheese ripening, can secrete compounds that induce allergic reactions in humans. Studies have shown that the opisthonotal glands of Astigmata secrete monoterpenes as well as various aromatic, aliphatic, and other compounds possessing pheromonal and fungicidal activities. A study of Cantal vieux showed that the main mite species was *Acarus siro* L. It has been proven that aromatic compounds released by mites do not penetrate the cheese matrix during ripening; instead, they contribute to flavor only upon rind consumption) (Shimizu et al., 2022). In Alpine and Yoghurt hard cheeses, *A. siro* contributes to rind aroma and flavor development, as well as rind formation and detachment from molds. By considering these results, it is advisable to develop rapid detection methods for mites on goat-milk hard-cheese rinds during ripening and to define their maximum permissible levels.

CONCLUSION

Moisture evaporation intensity is a crucial factor in ripening craft hard cheeses from raw goat milk. Between day 7 and month 6, Alpine cheese experienced its greatest moisture loss with 43.31% to 30.84%. Moisture content and hardness exhibited a strong inverse correlation with age, while fat content correlated positively. Increased dry matter corresponded with higher protein, fat, and ash levels. Cheese hardness declined to 44.05 units at 6 months and to 42.34 units at 12 months, reflecting increased fragility due to moisture loss. Aging also increased eye formation and produced an amber rind bearing mite *A. siro* damage and activity traces. Moisture loss drove changes in Yoghurt cheese physiological parameters, exhibiting a a strong inverse correlation with ripening duration. The highest moisture loss of Yogurtovy cheese was detected in the period from the 7th day to the 6th month of ripening, which decreased from 46.91% to 36.54%. By the 18th month of ripening of Yogurtovy cheese, its moisture reached 29.91%, which is associated with the peculiarity of crust formation.Rising dry matter corresponded with higher protein, fat, and ash contents. Hardness demonstrated a strong inverse relationship with age. Aging produced an amber rind and a brittle paste by 18 months. The rind displayed minor *A. siro* damage. These findings enrich understanding of physicochemical evolution in mite-ripened, raw-goat-milk hard cheeses.

DECLARATIONS

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Authors' contribution

Viktor Davydovych and Larysa Shevchenko contribute to the research, data analysis, and manuscript writing.
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Software: L.Shevchenko, V.Tomchuk, and O.Sydorenko.
Supervision: V.Nedashkivskyi, and N.Slobodyanyuk
Validation: N.Nesterenko, and N.Slobodyanyuk..
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Writing – review & editing: A.Ivaniuta, and V.Nedashkivskyi.

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Competing interests

The authors declare no competing interests in this research and publication.

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