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INFLUENCE OF AGING TIME ON THE PHYSICOCHEMICAL CHARACTERISTICS OF CRAFT SOFT CHEESES MADE FROM UNPASTEURIZED GOAT'S MILK

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Abstract

The expansion of craft cheese production from unpasteurized goat milk as health food products in the Ukrainian market requires the development of criteria for their quality and authenticity during ripening. The study aimed to determine the effect of ripening time on the physicochemical characteristics of brine Feta cheese and soft Chevre cheese with white mould. During 30 months of ripening, the moisture and protein content of Feta cheese did not change, fat increased by 3.03%, and ash decreased by 0.76%. The shelf life of Feta cheese did not affect its quality but changed the texture, which at the age of 18 and 30 months was characterised by compaction and increased brittleness. On the 40th day of ripening of Chevre cheese, the moisture content decreased by 4.30%, protein increased by 3.13%, and fat and ash did not change. The rind of Chevre cheese on the 20-40th day of ripening was covered with a characteristic white mycelium of mould fungi, the core was characterised by a granular structure, which with increasing ripening time was separated from the rind by a paste that flowed out when cut. The physicochemical characteristics of craft goat cheeses Feta and Chevre made from unpasteurised goat milk can be combined with other criteria to determine their quality, shelf life and authenticity.

Keywords: Feta cheese, Chevre cheese, moisture, texture, protein, fat, ash

INTRODUCTION

It is known that to ensure human life and well-being, nutrients and biologically active substances (proteins, fats, carbohydrates, macro- and microelements) are necessary (Ussembayeva *et al.*, 2024). The increasing demand for healthy food among consumers drives the expansion of the range of products on the food market, particularly cheeses made from unpasteurised goat's milk. It is known that the production of craft goat cheeses takes place on small farms, where the production, milk processing, cheese making, and their sale are combined. Craft cheese production has advantages over industrial

production due to the reduction of the burden of livestock farming on the ecological system and adherence to the concept of One Health. Among the range of popular goat cheeses, a special place is occupied by soft cheeses, in particular, brine cheese such as Feta with a long ripening and storage period, and soft Chevre cheese, which is characterised by a short ripening period with the participation of white noble mould (FAO & WHO, 2021). The production of these cheeses from unpasteurised goat milk gives them unique sensory characteristics. The most significant influence on consumer perception is the taste of the cheese, which is also one of the most important quality indicators (Han *et al*., 2019). Controlling the production and ripening process of cheeses is a significant challenge for its producers, as it requires taking into account a significant number of factors that can affect its taste, aroma and quality, such as raw material – unpasteurised milk, which has a dynamic microbiome, as well as the conditions and duration of ripening and storage (Iakubchak *et al*., 2024; Bord *et al*., 2025).

The wide variety of cheeses produced in different regions of the world determines the uniqueness of their tastes, aromas, textures and shapes. The constantly growing consumer demand for food products that can positively affect the functional state of the body stimulates the introduction of new technologies for cheese production and the improvement of their recipes (Rogoskii *et al*., 2020; Chaharovskyi *et al*., 2023; Ladyka *et al*., 2024). The modern range includes two types of cheeses: cheeses made using industrial technology and craft cheeses.

Cheese in industrial conditions is most often made from pasteurised animal milk to obtain a more standardised product in terms of chemical composition and organoleptic properties (Hammam *et al*., 2021). Craft cheeses are made from unpasteurised sheep and goat milk and their blends, which gives them a more significant number of flavour shades provided by the natural microflora and specific ripening and storage conditions. The milk of goats raised in specific regions is characterized by certain features determined by the climatic conditions, grazing management, and the botanical and chemical composition of the pasture (Kalit *et al*., 2024). The quality of milk used for cheese production is significantly affected by the season of production, as well as the breed and health of the animals (Hovjecki *et al*., 2022; Mylostyvyi *et al*., 2023; Oliynyk *et al*., 2024). The criteria for assessing the quality and attractiveness of cheeses for the consumer are structure, appearance, and internal texture.

Soft cheeses occupy an important place in consumer demand (Atallah *et al*., 2022). The most popular are white brine cheeses, which are consumed both independently and as part of other dishes, for example, salads, side dishes, and snacks. Feta brine cheese is very popular not only among the Baltic countries and Western Europe (Bouroutzika *et al*., 2021). In Ukraine, it is also becoming increasingly popular and is made not only from sheep's and cow's milk but also from unpasteurised goat's milk. This cheese does not have a characteristic cheese rind and is characterised by a combination of sour and salty taste, as it is ripened and stored in brine in containers made of various materials (Spyrelli *et al*., 2020; Thodis *et al*., 2023).

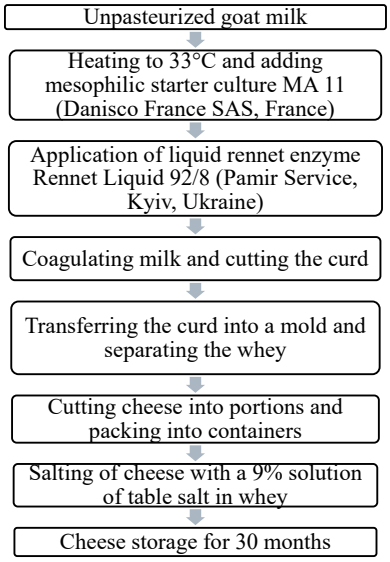
The complex dynamics and interactions between microorganisms that dominate milk create conditions that promote the transformation of milk proteins, fats and carbohydrates into constituent components that determine the sensory properties of cheese (Bal-Prylypko *et al*., 2024). Specific changes occur during cheese ripening, in particular proteolysis and lipolysis are important biochemical processes responsible for the development of taste, aroma and texture formation. This often necessitates long-term storage of brine cheeses, which involves studying the dynamics of their physicochemical characteristics and assessing quality and safety throughout the shelf life (Ferraz *et al*., 2024).

No less popular among consumers are cheeses that ripen with the participation of white noble mould. These cheeses have special organoleptic characteristics that depend on the raw materials from which they are produced, ripening technology and differ even within the same name. Such cheeses are an integral part of the consumer basket and occupy an honorable place on the table as components of sandwiches, vegetable and meat salads, desserts, as well as independent snacks. Soft cheeses with white mould belong to the group of rennet cheeses, which, thanks to mould fungi, form an exquisite taste, unique aroma and specific texture. The soft, in some cheeses, caramel-like or liquid texture, bordering on a white crust, gives such cheeses a unique appeal. Most often, white mould cheeses are made from pasteurised milk in the form of small cylinders and have a rich, simultaneously salty and mushroomy taste, as well as an earthy aroma, which is given to them by mould fungi, in particular *Penicillium camemberti.* Most cheeses ripened with white mould are traditionally produced in the Camembert (Normandy) region of France (Zhang *et al*., 2022); however, their range has been increasing recently in Eastern European countries, particularly in Ukraine. Moreover, cheese factories focus on small organic farms that specialise in producing goat or sheep milk and processing it into cheese. The production of craft cheeses, especially soft ones, which are characterised by different ripening or storage periods, requires the establishment of criteria for determining their age, quality and authenticity.

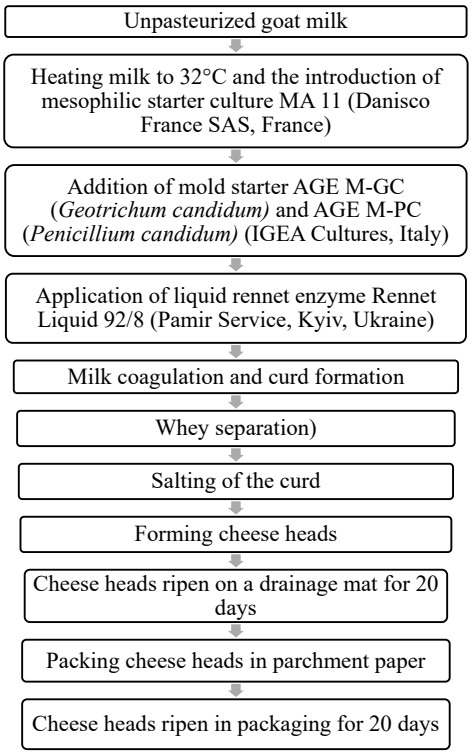
This study aimed to determine the effect of ripening time on the physicochemical parameters of craft soft cheeses made from unpasteurised goat's milk: brined Feta cheese and white mould Chevre cheese.

MATERIALS AND METHODS

Brine Feta cheese and Chevre cheese with white noble mould were produced in the Eco Farm "Zhuravka" conditions in the Kyiv region, Ukraine, from May 2022 to December 2024. Five batches of Feta cheese, each weighing 5 kg, and 15 heads of Chevre cheese, each weighing 180–200 g (Fig. 1, 2), were used for the research. The cheeses are made from the milk of Anglo-Nubian goats raised using natural pastures.



1: *Scheme of making brined Feta cheese*



2: *Scheme for making soft white mould Chevre cheese*

For the study, samples of Feta cheese were taken on the 7th day, 18th, and 30th month of ripening, with five samples weighing 200–250 g from each batch. Samples of Chevre cheese in the amount of 5 heads were taken for the study on the 3rd, 20th and 40th day of ripening.

Chemical analysis of soft craft goat cheeses was conducted at the testing centre of the State Scientific Research Institute of 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 moisture content in the cheeses was determined using the drying method, with samples dried in a VENTICELL drying oven (BMT, Czech Republic), through consecutive weighings and bringing the sample to a constant weight. The dry matter content in the samples was determined by the difference in the mass of the sample before and after drying. The protein content in the cheese samples was determined using the Kjeldahl method. The cheese samples were mineralised in an automatic Velp mineraliser Scientifica (DKL 12, Italy) and a steam semi-automatic distiller UDK 139 (Velp Scientifica, Italy). Ammonia, after the mineralization of cheese samples, was distilled using an automatic steam distillation apparatus according to Kjeldahl, Velp Scientifica (DKL 12, Italy). The amount of fat in cheeses was determined by the Gerber method. Samples were centrifuged in a Nova Safety centrifuge (Funke-Gerber, Germany). The ash content in cheeses was determined by the method of burning organic matter in a SNOL muffle furnace (Utenoselkerotechnika, Germany) with subsequent weighing of the mineral residue.

The results of the chemical composition analyses of the cheeses were processed using a one-way analysis of variance. The dynamics of changes in individual indicators of the chemical composition of Feta and Chevre cheeses were analysed using correlation and regression analysis. Microsoft Excel 2016 and XLSTAT software (Addinsoft, Paris & France, 2017) were used for statistical analysis. Digital data are presented as x ± SD (mean ± standard deviation). The comparison of the indicators was made within the same type of cheese over time. The indicator difference was considered significant at $P < 0.05$ using the Tukey test with Bonferroni correction.

RESULTS

Physicochemical Characteristics of Brined Feta Cheese Made from Unpasteurised Goat Milk During Ripening

During the ripening period of Feta cheese from unpasteurised goat milk, no moisture and protein content changes were observed, which is associated with its storage in sealed containers in a saline whey solution. At the same time, an increase in

I: *Chemical composition of craft brined Feta cheese, (%)*

Indicator	Ripening period		
	7 days	18 months	30 months
Humidity	44.96 ± 1.60[a]	43.52 ± 1.65[a]	44.86 ± 1.41[a]
Fat	25.51 ± 1.87[a]	28.18 ± 1.51[ab]	28.54 ± 0.65[b]
Protein	19.29 ± 0.18[a]	19.43 ± 0.30[a]	20.18 ± 0.73[a]
Ash	2.88 ± 0.47[ab]	3.25 ± 0.26[a]	2.49 ± 0.21[b]

[a, b, c] show the significant difference between the mean values in the table row (P < 0.05)

fat content by 3.03% was found in the 30-month-old cheese compared to the 7-day-old cheese and a decrease in ash content by 0.76% compared to the 18-month-old cheese (Tab. I).

The protein content in the dry matter of Feta cheese did not change, and the fat content was characterised by a strong direct dependence on the term of its ripening (r = 0.821 ± 0.108, P < 0.01) (Tab. II).

The regression line confirmed the existence of a direct linear relationship between the ripening period and the fat content in the dry matter of Feta cheese (Fig. 3). The fat-to-protein ratio in this cheese's dry matter was independent of the storage period.

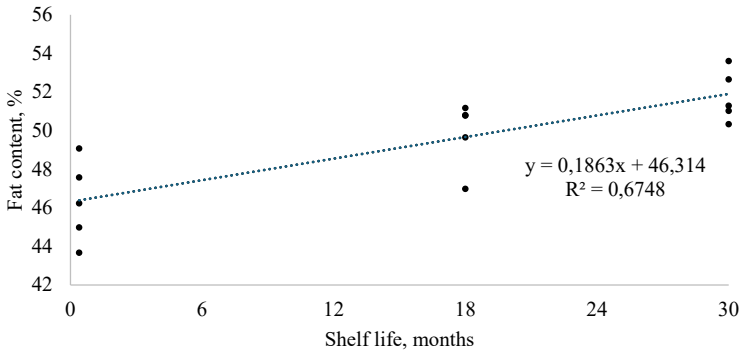
II: *Chemical composition of dry matter of craft brined Feta cheese, (%)*

Indicator	Ripening period		
	7 days	18 months	30 months
Fat, %	46.30 ± 2.12[a]	49.87 ± 1.71[b]	51.78 ± 1.32[b]
Protein, %	35.08 ± 1.12[a]	34.42 ± 1.11[a]	36.63 ± 1.67[a]
Fat/ protein ratio, units	1.32 ± 0.10[a]	1.45 ± 0.08[a]	1.41 ± 0.04[a]

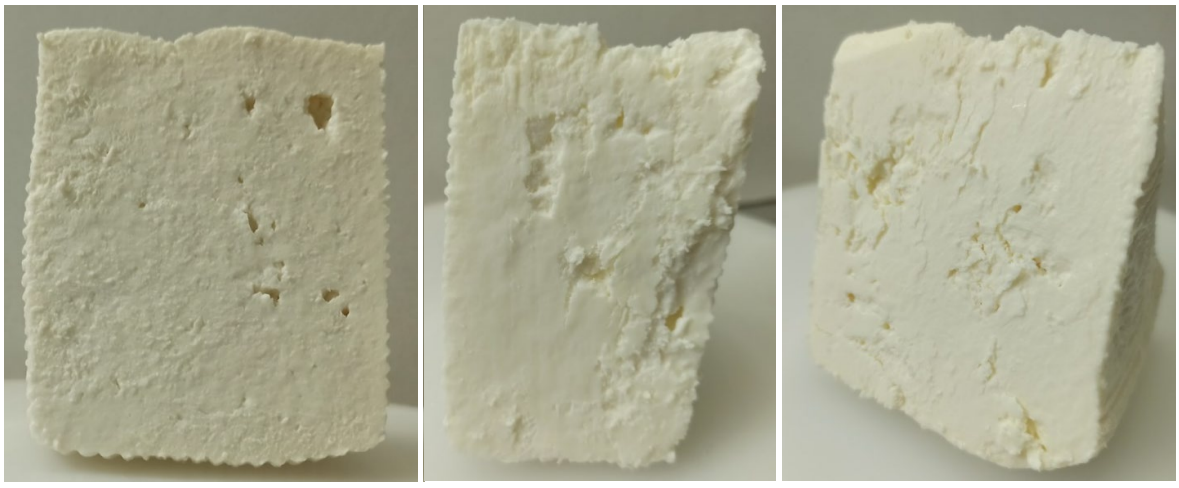
[a, b, c] show the significant difference between the mean values in the table row (P < 0.05)

Feta cheese with a 7-day ripening period was characterised by a plastic texture without a rind, on the cut of which medium—and small-sized pores were distinguished, unevenly located on its surface (Fig. 4a).

This cheese was easily cut into thin slices with a knife, its texture had a fine-grained appearance. At the age of 18 months, Feta cheese differed significantly in texture compared to young cheese. It had a less pronounced surface graininess, and the texture was brittle. The cut revealed



3: *Dependence of fat content in dry matter on the shelf life of Feta cheese, n = 15*



a *b* *c*

4: *Slice of Feta cheese with a ripening period: a – 7 days; b – 18 months; c – 30 months*

irregularly shaped cells that formed as a result of the compaction of the cheese structure during the ripening period (Fig. 4b). Old-ripened Feta cheese (30 months) was characterised by a brittle texture and had a dense consistency when cut. In terms of its characteristics, it differed little from the 18-month-old cheese (Fig. 4c).

Physicochemical Characteristics of Soft White Mould Chevre Cheese Made from Unpasteurised Goat Milk During Ripening

Chevre cheese was characterised by a decrease in moisture content by 4.30% on the 40th day compared to the age of 3 days and by 4.27% compared to the age of 20 days. The fat and ash content did not depend on the ripening period of Chevre cheese, while the protein content significantly increased by 0.96% on the 20th day and by 3.13% on the 40th day compared to the cheese aged 3 days (Tab. III).

Dry matter analysis showed that the fat content in Chevre cheese decreased with age, in particular from the 3rd to the 40th day, by 5.44%, while the protein content during the same period, on the contrary, increased by 3.31% (Tab. IV).

According to the fat and protein content in dry matter, their ratio decreased with increasing ripening period of Chevre cheese, particularly on the 20th day by 0.15 units and on the 40th day by 0.24 units compared to this indicator on the third day. A strong inverse dependence of fat content ($r = -0.783 \pm 0.117$, $P < 0.01$) and a strong direct dependence of protein content ($r = 0.728 \pm 0.129$, $P < 0.01$) in dry matter on the ripening period of Chevre cheese were found. Regression analysis confirmed the presence of a linear relationship between fat and protein content and the ripening period of this cheese (Fig. 5).

On the third day of ripening, the heads of Chevre cheese had a grainy consistency. The rind was absent, and the cheese texture had a brittle structure (Fig. 6a, b). On the 20th day of ripening, the heads of this cheese were covered with a rind with a well-pronounced white mycelium of mould fungi. The cheese texture loosely adhered to the rind on the cut and had a grainy structure. Between the rind and the cheese core, a zone filled with a paste, which was similar in consistency to liquid caramel, was clearly visible (Fig. 6c, d).

Ripening of Chevre cheese from 20 to 40 days of age, packed in parchment paper to reduce moisture loss, provided a homogeneous dense rind with a white colour, which held its shape well. On the cross-section, the core of the cheese had a grainy surface, which was separated from the rind by a layer of light-yellow paste with a consistency of liquid caramel (Fig. 6e, f). Compared with the 20-day-old cheese, the 40-day-old cheese had a higher content of pasty mass, which flowed out when the head was cut.

III: *Chemical composition of craft soft Chevre cheese, (%)*

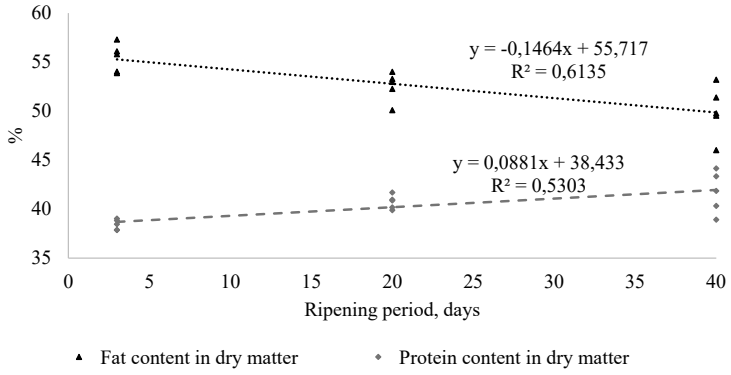
Indicator	Cheese ripening period, days		
	3	20	40
Humidity	58.98 ± 0.17[a]	58.95 ± 0.63[a]	54.68 ± 2.01[b]
Fat	22.73 ± 0.65[a]	21.55 ± 0.39[a]	22.61 ± 0.62[a]
Protein	15.75 ± 0.25[a]	16.71 ± 0.24[b]	18.88 ± 0.65[c]
Ash	2.05 ± 0.07[a]	2.02 ± 0.06[a]	1.99 ± 0.12[a]

[a, b, c] show the significant difference between the mean values in the table row ($P < 0.05$)

IV: *Chemical composition of dry matter of craft soft Chevre cheese, (%)*

Indicator	Cheese ripening period, days		
	3	20	40
Fat	55.42 ± 1.45[a]	52.53 ± 1.50[ab]	49.98 ± 2.66[b]
Protein	38.41 ± 0.53[a]	40.71 ± 0.71[ab]	41.72 ± 1.14[b]
Fat/ protein ratio	1.44 ± 0.03[a]	1.29 ± 0.02[b]	1.20 ± 0.02[c]

[a, b, c] show the significant difference between the mean values in the table row ($P < 0.05$)



5: *Dependence of fat and protein content in dry matter on the ripening period of Chevre cheese, n = 15*

6: *Chevre cheese with ripening period: 3 days (a – head, b – on the cut); 20 days (c – head, d – on the cut); 40 days (e – head, f – on the cut)*

DISCUSSION

The production of cheeses under the conditions of a single goat farm determines the similarity of the microbiological, physicochemical, and sensory characteristics of the raw material – milk, however, different soft cheese production technologies give originality to their chemical composition, physical, and sensory properties. Physico-chemical analysis of dairy products, particularly goat cheeses, is an important tool for determining not only their quality but also their ripening period and authenticity (Sadvari *et al*., 2024a; Sadvari *et al*., 2024b). Feta cheese made from whole milk should contain 45–60% moisture, 15–20% protein, 10–20% fat, and 5–10% salt (Zonoubi, *et al*., 2020). The results of the chemical composition of brined Feta cheese in our studies exceeded the above similar data on fat content and were more similar to the composition of Bryndza goat cheese made from unpasteurised goat milk (Kováčová *et al*., 2021), as well as goat cheese made from organic milk (Popović- Vranješ *et al*., 2016), where the fat level was in the range of 25.3–32.9%. Our results also revealed higher fat, protein and dry matter, excluding ash content, than in industrially produced Feta cheese, which was stored for 180 days in stainless steel containers and

tin cans (Massouras *et al*., 2023). It is believed that the physicochemical parameters of brine cheeses such as Feta are determined by the characteristics of the composition of soils, water, grass cover and geographical location of the area (Gatzias *et al*., 2020 Regulation (EU) 2024/1143). Although the ripening period of Feta cheese is 60 days, it can be stored in brine for much longer, but this needs to be justified.

One of the important criteria for assessing the quality of cheeses is the content of fat and protein in dry matter and their ratio, as this plays an important role in shaping the sensory characteristics and quality of cheeses (Mladenović *et al*., 2022). The fat content data obtained by us are consistent with the results of Massouras *et al*. (2023), who found fluctuations of this indicator in Feta cheese during the ripening (storage) period, ranging from 49.9% to 53.59%. As for the protein content in dry matter, in this study, after the 60th day, it was in the range of 34.26–36.24%, reaching a maximum on the 90th day of storage of Feta cheese. In parallel, an increase in the protein content in the brine was found, which the researchers explain by the probable release of proteins from the cheese into the brine. In our study, we did not observe changes in the protein content in the dry matter of Feta cheese that would confirm this assumption.

The ash content of Feta cheese was significantly influenced by the level of table salt, which on the 60th day was 2.77–3.24% (Massouras *et al*., 2023). This study found an increase in the ash content of Feta cheese with storage time from 3.29 to 3.74% and from 3.44 to 3.81% depending on the container in which the cheese was stored. Our data showed that during ripening for 30 months, the ash content of Feta cheese decreased slightly, which is probably due to a change in its internal texture.

Ripening involves a complex chain of chemical processes that can transform the cheese mass into the appropriate type of cheese with a characteristic appearance, shape, texture, and composition of aromas and flavours (Álvarez and Fresno, 2021; Szkolnicka *et al*., 2024). All these processes affect the quality of the cheese and are determined by the intensity of the processes of lipolysis, proteolysis and glycolysis. A feature of the formation of the texture of Feta cheese is the absence of pores on the cut of the texture, which are formed by carbon dioxide, while mechanical pores resulting from pressing the cheese mass are desirable (Geronikou *et al*., 2020). As can be seen from the data we obtained, Feta cheese was characterised by the presence of pores at a young age (7 days), while at the 18th and 30th months of storage in brine, such pores were not detected, which is associated with the compaction of the cheese mass, its increased fragility and the appearance of mechanical cracks. The ripening conditions of Feta cheese determine the intensity and direction of changes in the paracasein network, which affects the formation of the physicochemical properties of the cheese. Feta-type cheeses made from goat milk are white. The texture of such cheeses is smooth and soft, and after prolonged ripening (storage), it becomes brittle (Alichanidis *et al*., 2008), which is fully consistent with our data from studies of 18- and 30-month-old goat Feta cheese. The shape of Feta cheese pieces is often made in cubic or rectangular blocks weighing 250–1 000 g. In our case, Feta cheese was placed for ripening and storage in food-grade plastic containers in the form of triangular blocks weighing 250–300 g, which changed little in their appearance starting from the age of 18 months. This complicates the establishment of the ripening or storage period of brine Feta cheese, and to achieve this goal requires the development of additional chemical and physical analytical criteria.

Unlike brine cheese Feta, which is suitable for long-term storage, soft Chevre cheese, which ripens with the involvement of white mould, quickly changes its physico-chemical and sensory characteristics, allowing for a more accurate determination of its age and quality. A feature of soft cheeses such as Camembert, which includes Chevre cheese from goat milk, is the intensity of growth of mycelium of mould fungi on the surface of the rind and their participation in the processes of lipolysis, proteolysis and glycolysis. It was found that in Camembert cheeses, the moisture content was 53.15–57.99%, Ca - 0.23–0.45%, and P - 0.21–0.40% during the ripening period of 50 days (Batty *et al*., 2019 b). In this case, the pH value was important, reaching seven units on the rind on the 7th–10th day and in the paste from the 35th to the 50th day. As for the chemical analysis of Chevre cheese made from unpasteurised goat milk, its moisture content approached Camembert cheese both at the beginning and at the end of the ripening period. The decrease in moisture content in such cheeses is associated with the ability of part of the water to evaporate into the atmosphere. The relative humidity in the ripening chambers for such cheeses is believed to be within 90–95% (Leclercq-Perlat *et al*., 2012). At a relative humidity in the ripening chamber above 95%, mould mycelium growth slows down, affecting the cheese's ripening and quality. On the other hand, at a humidity below 90% in the ripening chamber, excessive water loss occurs by the cheese heads, and they become too dry, affecting their taste and consistency and reducing consumer demand. The total water loss during the ripening of Camembert-type cheeses is considered acceptable within 10–15%, and the water evaporation intensity is 1.6 ± 0.3 g/day. In our study, Chevre cheese practically did not lose moisture during the ripening period from the 3rd to the 20th day, and at the age of 40 days, this value did not exceed 4.5% compared to the initial level, which is also important in stimulating or limiting the growth of certain types of undesirable microorganisms. Such low moisture loss by Chevre cheese during ripening is explained by wrapping the heads with greaseproof parchment paper, which

prevents moisture evaporation. A similar technology is used when ripening Camembert-type cheese (Szkolnicka *et al*., 2024).

As can be seen from the analyses obtained, the content of dry matter, fat and protein in Chevre cheese was within the limits typical for such cheeses, which is consistent with the results of other studies (Batty *et al*., 2019a). During the ripening of Chevre cheese, a decrease in fat content and an increase in protein content in dry matter were observed at the end of the ripening period, which is probably due, on the one hand, to lipolysis and proteolysis carried out by mould fungi, and on the other hand, to the intensive growth of their mycelium. This assumption is confirmed by the fact that the ratio of fat to protein in the dry matter of cheese decreases with increasing ripening time. It has been proven that at the beginning of the ripening process of cheeses with a rind, yeasts, which are part of their microbiome, actively metabolise lactic acid and form ammonia while deaminating amino acids. This, in turn, contributes to a sharp increase in the pH value of the cheese surface and creates favourable conditions for the further growth of mould microorganisms such as *Debaryomyces hansenii* and *Geotrichum candidum* and over 30 other species (Fröhlich-Wyder *et al*., 2019).

An important criterion for the consumer appeal of Camembert-type cheeses is their appearance and texture when cut. A feature of this cheese type is the soft texture with a characteristic oozing of the paste when the head is cut (Batty *et al*., 2019 a). In this study, it ranged within 27 ± 1.9 mm on the 50th day of ripening of Camembert-type cheese for 1 hour. Chevre cheese had a characteristic feature, which was expressed in the appearance between the rind and the core of a paste with the consistency of liquid caramel, the volume of which increased with increasing ripening time. Such cheese combined a grainy texture in the core and a liquid texture in the rind area, which makes it unique and allows for determining its age and authenticity.

CONCLUSION

It has been established that brined Feta cheese made from unpasteurised goat milk is suitable for storage for 30 months in a whey salt brine in airtight food-grade plastic containers. This is confirmed by the stable protein and moisture content, the ratio of fat to protein in the dry matter and minor fluctuations in the fat and ash content. Although the structure of Feta cheese undergoes changes during the ripening period, it becomes more fragile, but the colour and texture correspond to a product of proper quality.

Chevre cheese from unpasteurised goat milk lasts up to the 40th day and is characterised by a loss of moisture at the level of 4.30% and an increase in protein content by 3.13%. With increasing age, a rind with white mycelium of mould fungi forms in Chevre cheese. A growing zone is formed between the rind and the core of the cheese, filled with a paste with the consistency of liquid caramel, which flows out when cut. This study is limited to the range of soft cheeses produced in one of the goat eco-farms of Ukraine. The data obtained may serve as a basis for determining the quality, ripening period (age) and authenticity of craft soft cheeses made from goat's milk in conjunction with the analysis of their fatty acid, mineral composition and microstructure.

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