UDC 637.35:577.115.3
DOI: 10.15587/1729-4061.2026.350220

ESTABLISHING THE DEPENDENCE OF FATTY ACIDS CONTENT AND LIPID QUALITY ON MATURITY TERM OF THE ALPINE AND YOGURT HARD GOAT CHEESES

Viktor Davydovych
Doctor of Philosophy (PhD)
Department of Animal and Food Hygiene named after Professor A.K. Skorokhodko*
ORCID: https://orcid.org/0000-0002-2864-9018
Larysa Shevchenko
Doctor of Veterinary Sciences, Professor
Department of Animal and Food Hygiene named after Professor A.K. Skorokhodko*
ORCID: https://orcid.org/0000-0001-7472-4325
Natalia Slobodyanyuk
PhD, Professor
Department of Technology of Meat, Fish and Marine Products*
ORCID: https://orcid.org/0000-0002-7724-2919
Svitlana Furman
PhD, Associate Professor
Department of Veterinary Epidemiology
Polissia National University
Staryi blvd,. 7, Zhytomyr, Ukraine, 10008
ORCID: https://orcid.org/0000-0002-1079-5797
Valentyna Bandura
Corresponding author
Doctor of Technical Sciences, Professor
Department of Processes and Equipment for Processing of Agricultural Products*
E-mail: vbandura@nubip.edu.ua
ORCID: https://orcid.org/0000-0001-8074-3020
Tetiana Lebedenko
Doctor of Technical Sciences, Professor**
ORCID: https://orcid.org/0000-0001-8385-4674
Olena Sydorenko
Doctor of Technical Sciences, Professor***
ORCID: https://orcid.org/0000-0001-5919-4370
Nataliia Kovalenko
PhD, Associate Professor**
ORCID: https://orcid.org/0000-0003-4167-5779
Natalia Nesterenko
PhD, Associate Professor
Department of Commodity Science and Pharmacy***
ORCID: https://orcid.org/0000-0003-3003-0406
*National University of Life and Environmental Sciences of Ukraine
Heroyiv Oborony str., 15, Kyiv, Ukraine, 03041
**Department of Hotel and Restaurant Business
Odesa National University of Technology
Kanatna str., 112, Odesa, Ukraine, 65039
***Department of Commodity Science and Pharmacy
State University of Trade and Marketing
Kyoto str., 19, Kyiv, Ukraine, 02156

The Alpine and Yogurt craft hard cheeses made from unpasteurized goat milk are studied in this paper. The task under consideration is to define the authenticity criteria for the Alpine and Yogurt craft goat cheeses made from unpasteurized milk during maturity process.

Consumers' orientation towards healthy eating leads to an increase in the supply of craft cheeses made from unpasteurized goat milk on the market, which involves assessing their quality, safety, and establishing authenticity criteria. Such indicators include the fatty acid composition and quality of milk fat lipids.

The fatty acid composition of the cheeses has been analyzed using gas chromatography. The lipid structure of both cheeses contained 15 fatty acids (11 saturated and 4 unsaturated). The share of saturated fatty acids increased by 4.04–4.44% at the 18th month of maturity of the Yogurt cheese and at the 6th month of maturity of the Alpine cheese.

During the maturity process, the proportion of polyunsaturated fatty acids in the Alpine cheese increased by 1.60–2.07%; in the Yogurt cheese by 1.24–2.35%. In both cheeses, the basis of ω-3 and ω-6 polyunsaturated fatty acids was linolenic and linoleic; their ratio ranged from 1:4.26 to 1:2.31.

The ripened Alpine and Yogurt cheeses were characterized by the highest indices of thrombogenicity and atherogenicity, in contrast to old-ripened cheeses, in which these indices decreased against the background of an increase in the indices of hypocholesterolemic/hypercholesterolemic acids and healthy fat. The delta nine desaturase index (C14) during maturity period of the Alpine cheese decreased by 0.010–0.011; in the Yogurt cheese, on the contrary, it increased by 0.054–0.026 units.

The fatty acid composition of goat craft hard cheeses could be a justification for devising criteria for their authenticity and nutritional value

Keywords: fatty acids, fat quality indices, unpasteurized milk, craft cheeses

Received 04.11.2025
Received in revised form 26.12.2025
Accepted date 13.01.2026
Published date 27.02.2026

How to Cite: *Davydovych, V., Shevchenko, L., Slobodyanyuk, N., Furman, S., Bandura, V., Lebedenko, T., Sydorenko, O., Kovalenko, N., Nesterenko, N. (2026). Establishing the dependence of fatty acids content and lipid quality on the ripening term of hard goat cheeses Alpine and Yogurt. Eastern-European Journal of Enterprise Technologies, 1 (11 (139)), 23–33. https://doi.org/10.15587/1729-4061.2026.350220*

1. Introduction

It is known that the production of cheeses from unpasteurized milk most often takes place at artisanal enterprises that simultaneously specialize in raising small cattle, obtaining milk, processing it, and selling small batches of dairy products. A number of well-known cheeses such as Caciorikotta, Pecorino di Filiano, Roquefort, and Serra da Estrela are made from unpasteurized milk. However, such production often faces significant risks, which are associated with maintaining proper hygiene in the production, maturity, and storage of cheeses, as well as determining their authenticity [1]. In many countries of the European Union and Africa, the practice of producing craft dairy products, in particular goat cheeses, is also widespread. Moreover, economic, political, and social conditions stimulate the development of small eco-farms at which new cheese making technologies are being improved and developed [2]. As a result of the increase in the supply of craft goat cheeses on the food market, there is a need to devise criteria for their authenticity, as well as for determining their age, quality, and safety for consumers.

One of the main indicators of the biological value, quality, and safety of hard cheeses is the characteristics of milk fat. Its content in cheeses determines the intensity of lipolysis processes, the duration of maturity, and is provided by the spectrum and ratio of a significant amount of fatty acids. At the same time, fatty acids are important not only nutritional, but also biologically active components that significantly affect human health [3]. Therefore, it is a relevant task to study the features of the fatty acid composition and quality of lipids depending on the maturity period of such cheeses.

2. Literature review and problem statement

Dairy products have always been and are an essential component in the diet of most people around the world; their range is constantly growing. This growth is characterized by the development of vegetarian, as well as elite natural dairy products. However, study [4] does not assess elite craft products, and issues related to determining their authenticity are also left unconsidered. At the same time, the quality control system for raw materials and the finished product is being improved [5]. These studies are more concerned with expanding the range of healthy industrial dairy products and do not take into account the conditions of craft production. Expanding quality requirements is one of the main criteria for consumer choice and positioning dairy products in the system of a healthy diet [6]. Although among the criteria for a healthy diet there are requirements for fatty acid composition, the cited study pays more attention to the use of vegetable milk concentrates to increase product yield. This somewhat limits the assessment of the quality and authenticity of the final product. Moreover, the use of plant ingredients in the recipe, although it reduces the cost of the product, makes it difficult to determine the adulteration of milk fat with vegetable fats.

Cheeses are among the most popular dairy products. They are made from the milk of cattle and small cattle, which includes a significant number of breeds of sheep and goats. In [7] it is noted that goat cheeses differ from other cheeses in the features of their chemical composition, the content of nutrients and biologically active substances, in particular the content and ratio of fat and protein. However, the study analyzed the physicochemical composition of soft and brine goat cheeses from unpasteurized goat milk, which does not reflect the regularities of the maturity processes in hard cheeses. Also, questions remain unresolved regarding the composition and quality of milk fat in hard goat cheeses during maturity, which complicates determining their authenticity.

It was this approach used in [8] that showed that goat milk fat is superior to sheep and cow milk fats in terms of the content of short-chain acids, as well as acids with an even number of carbon chains and branched-chain acids. This is reflected even in the names of saturated fatty acids, which include caproic (C6:0), caprylic (C8:0), and capric (C10:0). The names of these acids come from the Latin term *Capra* – goat. At the same time, goat cheeses contain significantly less butyric (C4:0), palmitic (C16:0), and stearic acids (C18:0). Such a content of fatty acids in goat milk fat allows one to consider them as a criterion of species affiliation in combination with other indicators of chemical composition and biological characteristics. However, in the cited study, goat milk cheeses were purchased on the market, which does not allow for an objective assessment of their recipe and limits the unification of maturity conditions and comparison of indicators in dynamics. The reason for this may be the rather significant cost of the research, which is associated with a long maturity period, the cost of refined old-ripened goat cheeses, as well as the high variability of factors in craft production.

In [9] it is shown that craft hard cheeses made from goat milk are in significant demand by consumers due to their unique nutritional and taste characteristics. The peculiarity of the tastes of such cheeses is determined by the use of unpasteurized milk for their production. Unlike cheeses made from pasteurized milk, cheeses made from raw milk are characterized by a rather dynamic and authentic microbiome. It provides the uniqueness of organoleptic shades, especially in mature and old-ripened cheeses. This is associated [10, 11] with a long maturity period, which in hard cheeses reaches 1–2 years or more. The formation of the taste of cheeses occurs due to the enzymatic activity of microorganisms in raw milk, which include a significant number of lactic acid bacteria, in particular *Lactobacillus spp.*, *Lactococcus spp.*, *Leuconostoc spp.* and *Enterococcus spp.* However, the cited studies did not focus on the features of the microbiome of cheeses from unpasteurized milk and its effect on the fatty acid composition and quality of milk fat. This approach limits the understanding of the nature of enzymatic processes in hard cheeses during their maturity. In cheeses from raw milk, these and other microorganisms are key and participate in the processes of lipolysis and proteolysis and synthesize a significant number of volatile compounds, in particular organic acids, alcohols, and esters, which determine the composition of its aromas.

According to a recent study [12], along with the exquisite taste, the benefits of raw goat milk cheeses for the human body are due to the most favorable fatty acid profile. The authors proved the dependence of the human immune response on the composition and ratio of fatty acids in the diet. Short-chain fatty acids (SCFA) reduce metabolic imbalance and the development of oncological pathology, and in combination with polyunsaturated fatty acids (PUFA) enhance the effectiveness of immunotherapy. However, the study on the inclusion of hard goat cheeses from unpasteurized goat milk in the human diet and the impact of fatty acid composition on its health has not been conducted, which reveals the prospects of such research.

Another work [13] notes the importance of regulating the human diet according to the content of polyunsaturated fatty acids, in particular ω-3 and ω-6. They ensure the structural integrity and fluidity of the cell membrane, participate in the regulation of glucose levels and other metabolites in the blood, contribute to the anti-inflammatory effect and improve blood clotting. It has also been proven that the most optimal ratio of ω-3/ω-6 fatty acids is found in goat milk fat, which allows us to recommend cheeses as potentially healthy food products.

However, in the cited study, the authors did not pay attention to other indicators of the quality of milk fat lipids, which does not allow us to compare the results of studies on goat cheeses from unpasteurized milk with a long maturity period. Questions remain unanswered regarding the quality of milk fat in hard goat cheeses during the maturity process, in particular young, mature, and old-ripened ones. A likely reason is much greater attention by scientists and producers to cheese safety indicators, in particular microbiological risks, contamination of milk with toxins, antibiotic residues and pesticides, which are regulated by regulatory documents.

The approach used to assess the quality of milk fat in [14] justifies the expansion of the list of these indicators. Of these, the most common are ΣSFA, ΣMUFA, ΣPUFA, ω-3 PUFA, ω-6 PUFA and ω-3 PUFA /ω-6 PUFA, as well as indices of atherogenicity, thrombogenicity, healthy fat, and others. Their development is due to the increase in consumer demand for healthy nutrition but is mostly limited to the assessment of cheeses purchased in the retail chain. This is largely related to monitoring the quality and safety of dairy products and does not make it possible to establish certain patterns in the dynamics of the fatty acid composition of cheeses depending on the maturity period. Therefore, the paucity of such studies to some extent limits their use as criteria for the authenticity of refined goat cheeses.

At the same time, despite the fact that the European Union markets present a significant list of names of various cheeses made using traditional technologies, the composition of fatty acids and quality indicators of milk fat have attracted little attention from researchers. This is evidenced by the analysis of scientific articles cited in international databases. Thus, out of 25,000 references to publications, the number of studies on the composition of fatty acids of individual cheese names reaches only a few dozen [15]. There is even less information on the dynamics of fatty acid content and lipid quality during the maturity process of hard cheeses. Analysis of the fatty acid profile and lipid quality in hard craft goat cheeses made from unpasteurized milk during a long maturity period has been covered only in a few studies. This indicates that there are a significant number of disagreements and debatable issues in the concept of healthy eating, including milk fat quality indicators.

All this gives reason to believe that research into the fatty acid composition and lipid quality of hard goat cheeses made from unpasteurized goat milk during maturity is appropriate.

3. The aim and objectives of the study

The aim of our study is to determine the dynamics in the content of fatty acids and, on their basis, to assess the quality of lipids of the Alpine and Yogurt craft hard cheeses made from unpasteurized goat milk, which ripen with the participation of the *Acarus siro* mite. This will allow us to establish criteria for authenticity, quality, and biological usefulness of craft hard goat cheeses.

To achieve the goal, it is necessary to solve the following tasks:

– to determine the fatty acid composition and define the dependence of lipid quality indices of the Alpine cheese on the maturity period;

– to determine the fatty acid composition and define the dependence of lipid quality indices of the Yogurt cheese on the maturity period.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our study was the Alpine and Yogurt craft hard cheeses made from unpasteurized goat milk.

The principal hypothesis assumes that the maturity period affects the fatty acid profile and milk fat quality of craft hard goat cheeses.

The assumption adopted in the study: identifying patterns in the dynamics of fatty acid content, as well as milk fat quality indicators in young, mature, and old-ripened Alpine and Yogurt cheeses could provide a basis for using them to assess quality, safety, and as a criterion for determining authenticity.

The simplification accepted in the work: unified conditions in the cheese maturity chamber, which also included the same density of colonization of the surface of the heads with the *A. siro* mite, the frequency and procedure for washing the heads, the same selection scheme and mass of cheese samples for the study, fatty acid composition and a list of milk fat quality indicators.

4. 2. Experimental material

The study used hard craft cheeses made from unpasteurized goat milk: Alpine and Yogurt whose manufacturing technology is described in [16]. Milk from Anglo-Nubian goats obtained at the Eco Farm "Zhuravka" in the Kyiv oblast was used for the production of cheeses. The study was carried out from May 2023 to January 2025.

For the analysis of the content of fatty acids, average samples of both cheeses weighing 200 g each from 5 heads were taken at each stage of maturity. Samples of the Alpine cheese were taken at the age of 7 days, 6 months, and 12 months; the Yogurt cheese – at the age of 7 days, 6 months, and 18 months, respectively. The selection of cheese samples for analysis was based on the assessment of the initial fatty acid composition of lipids and their quality, which corresponded to the 7-day age of both cheeses. According to the indicators of physicochemical composition, cheeses of both brands were characterized as mature at the age of 6 months; as old-ripened, at the age of 12 and 18 months.

4. 3. Research methods

To determine the content of fatty acids in cheese lipids, their extraction was carried out [17] followed by hydrolysis and methylation of fatty acids [18]. The study of the content of fatty acid methyl esters was carried out using gas chromatography Trace GC Ultra (USA) with a flame-ionization detector and an injector with temperature programming on a SPTM-2560 high-polar capillary column (Supelco, USA), length 100 m, with an inner diameter of 0.25 mm and a thickness of the stationary phase of 0.20 μm. Chromatography was carried out under the following conditions: column temperature 140–240°C, detector temperature 260°C. The sample was introduced into the chromatograph using a TriPlus autosampler in a dose of 1 μl. Analysis of the content of fatty acids in each cheese sample lasted an average of 65 min.

For the identification of fatty acids, the standard sample Supelco 37 Component FAME Mix was used. The content of fatty acids in the lipid structure of cheeses was determined in percentages by the internal normalization method. The fatty acid composition of cheeses was performed in 3 replicates. The content of the following fatty acids was determined in cheeses: butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), hendecanoic (C11:0), lauric (C12:0), myristic (C14:0), myristoleic (C14:1), pentadecanoic (C15:0), palmitic (C16:0), stearic (C18:0), oleic (C18:1ω9), linoleic (C18:2ω-6), linolenic (C18:3ω-3), arachidic (C20:0).

To assess the quality of lipids in cheeses, calculations were made of the total content of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), unsaturated fatty acids (UFA), short-chain fatty acids (SCFA, C4–8), medium-chain fatty acids (MCFA, C10–16), long-chain fatty acids (LCFA, C17–20).

The quality of lipids in hard cheeses was also determined by separate indices using the calculation method. Δ^9 desaturase Index (C_{14}) was calculated, according to [19], from formula (1)

$$\Delta^9 \text{ desaturase Index } (C_{14}) = C14{:}1 / (C14{:}1 + C14{:}0). \quad (1)$$

This index shows the ratio of the sum of the main saturated to the main unsaturated fatty acids of fat. Saturated fatty acids are proatherogenic, which are able to increase the adhesion of lipids to cells of the immune and circulatory systems. Unsaturated fatty acids are considered antiatherogenic since they reduce the level of esterified fats and prevent micro- and macrocoronary pathologies. The fatty acid C14:0 has a 4-fold higher atherogenicity than other fatty acids, therefore it is assigned a coefficient of 4.

The content of hypocholesterolemic fatty acids (DFA) in cheeses was calculated, according to [20], from formula (2)

$$\text{DFA} = \text{MUFA} + \text{PUFA} + C18{:}0. \quad (2)$$

To calculate the content of hypercholesterolemic fatty acids (OFA), formula (3) was used from [20]

$$\text{OFA} = C12{:}0 + C14{:}0 + C16{:}0. \quad (3)$$

Hypocholesterolaemic/hypercholesterolaemic ratio (H/H) was calculated, using [21], from formula (4)

$$\text{H/H} = \frac{\left(C18{:}1n-9 + C18{:}2n-6 + C18{:}3n-3\right)}{\left(C12{:}0 + C14{:}0 + C16{:}0\right)}. \quad (4)$$

The ratio of the sum of saturated fatty acids C14, C16, and C18 (prothrombogenic) to unsaturated (antithrombogenic) is expressed by the thrombogenicity index (IT). Fatty acids $n-6$ and monounsaturated fatty acids are assigned a coefficient of 0.5 due to their significantly lower atherogenicity than polyunsaturated fatty acids $n-3$, which are assigned a coefficient of 3. IT characterizes the ability of fat to form blood clots in vessels. IT was calculated, according to [22], from formula (5)

$$\text{IT} = C14 + C16 + {} + C18 / \left[\begin{array}{l}\left(0.5\text{MUFA} + 0.5\text{PUFA}n-6 + 3\text{PUFA}n-3\right) + \\ +\text{PUFA}n-3/\text{PUFA}n-6\end{array}\right]. \quad (5)$$

Atherogenicity index (AI) was calculated, according to [22], from formula (6)

$$\text{IA} = [C12{:}0 + (4 \times C14{:}0) + C16{:}0]/(\text{MUFA} + \text{PUFA}). \quad (6)$$

To objectively assess the nutritional value and health-promoting properties of individual fatty acids involved in the occurrence of cardiovascular pathology, their weighted coefficients were taken into account in calculating the healthy fat index (HFI). To calculate this index, formula (7) was used from [23]

$$\text{HFI} = \frac{\left[\begin{array}{l}(\text{MUFA} \times 2) + (n-6 \times 4) + \\ +(n-3 \times 8) + (n-3/n-6)\end{array}\right]}{\left[\begin{array}{l}(\text{SFA} \times 1) + (\text{MUFA} \times 0.5) + (n-6 \times 0.25) + \\ +(n-3 \times 0.125) + (n-6/n-3)\end{array}\right]}. \quad (7)$$

It is believed that HFI, unlike AI and IT, is a direct indicator of the presence of healthy fat in the product.

4. 4. Statistical analysis

Statistical processing of our study's results was carried out using one-way analysis of variance (ANOVA). Digital material was subjected to regression analysis, data in the tables are represented as $x \pm SD$ (mean ± standard deviation). For this purpose, Microsoft Excel 2021 (USA) and XLSTAT (France) software were used. The difference was calculated based on the indicators of fatty acid composition and lipid quality within each hard cheese type depending on the maturity period, which was considered significant using the Tukey test at $P < 0.05$ (taking into account the Bonferroni correction).

5. Results of investigating the fatty acid composition and lipid quality of the Alpine and Yogurt cheeses

5. 1. Results of investigating the dynamics in the fatty acid composition and lipid quality of the Alpine cheese

Our analysis of the Alpine cheese revealed that the proportion of saturated fatty acids depended on the period of its maturity: it reached its maximum at the 6th month and decreased by 2.37% at the 12th month compared to the initial level on the 7th day (Tables 1, 2).

Table 1

Dynamics of fatty acid content in the Alpine cheese made from unpasteurized goat milk during maturity with the participation of *Acarus siro* mites (% of the total fatty acid content) ($x \pm SD$, $n = 5$)

Acid	Cheese maturity period		
	7 days	6 months	12 months
Butyric acid, C 4:0	2.47 ± 0.06^a	2.42 ± 0.19^a	2.78 ± 0.10^b
Caproic acid, C 6:0	2.78 ± 0.06^a	3.91 ± 0.22^b	3.16 ± 0.24^c
Caprylic acid, C 8:0	3.13 ± 0.04^a	3.80 ± 0.12^b	3.03 ± 0.11^a
Capric acid, C 10:0	9.55 ± 0.21^a	12.29 ± 0.23^b	7.98 ± 0.28^c
Hendecanoic acid, C 11:0	0.26 ± 0.03^a	0.17 ± 0.01^b	0.24 ± 0.02^a
Lauric acid, C 12:0	3.36 ± 0.10^a	3.94 ± 0.14^b	3.71 ± 0.32^{ab}
Myristic acid, C 14:0	9.41 ± 0.16^a	8.21 ± 0.14^b	8.04 ± 0.25^b
Myristoleic acid, C 14:1	0.56 ± 0.04^a	0.40 ± 0.03^b	0.41 ± 0.03^b
Pentadecanoic acid, C 15:0	0.70 ± 0.01^a	0.63 ± 0.05^a	0.73 ± 0.03^a
Palmitic acid, C 16:0	22.41 ± 0.22^a	21.50 ± 0.72^b	22.59 ± 0.26^a
Stearic acid, C 18:0	14.42 ± 0.19^a	15.96 ± 0.49^b	13.39 ± 0.37^c
Oleic acid, C 18:1n9c	27.92 ± 0.15^a	21.65 ± 0.34^b	28.37 ± 0.25^a
Linoleic acid, C 18:2n6c	2.08 ± 0.07^a	3.49 ± 0.11^b	3.34 ± 0.23^b
Arachidic acid, C 20:0	0.33 ± 0.02^a	0.82 ± 0.05^b	0.79 ± 0.03^b
Linolenic acid, C 18:3n3	0.63 ± 0.03^a	0.83 ± 0.12^b	1.45 ± 0.07^c

Note: superscript letters $^{a, b, c}$ indicate a significant difference between values in the same row of the table ($P < 0.05$).

Such changes are primarily associated with similar fluctuations in the total content of short-chain, medium-chain, and individual long-chain fatty acids in the fat structure of this cheese. Among the saturated fatty acids in the Alpine cheese, caproic, caprylic, capric, lauric, stearic, and arachidic reached their peak at the 6th month with a further decrease in the proportion by the 12th month of maturity. The highest content of butyric, pentadecanoic, and palmitic acids in the Alpine cheese was found at the 12th month of maturity, and hendecanoic and myristic acids in young cheese compared to mature and old-ripened.

In accordance with the change in the ratio of saturated acids, the proportion of unsaturated fatty acids was characterized by significant fluctuations throughout the maturity period of the hard Alpine cheese. At the 6th month of maturity, the content of unsaturated acids in this cheese decreased by 7.83%, while at the 12th month it exceeded the similar indicator of young cheese aged 7 days by 2.37%. The decrease in the proportion of unsaturated fatty acids in the fat composition of the Alpine cheese at the 6th month of maturity occurred due to a decrease in the content of monounsaturated fatty acids by 6.42%, in particular myristoleic by 0.16% and oleic by 6.27% compared to the similar indicators of cheese aged 7 days (Tables 1, 2).

As for the dynamics of polyunsaturated fatty acids in the Alpine cheese, it was characterized by a direct dependence on its maturity period. As the regression line showed, this dependence was expressed by a second-power polynomial (Fig. 1).

At the same time, an increase in the proportion of polyunsaturated fatty acids in the Alpine cheese was found at the 6th month of maturation by 1.6% and at the 12th month of maturation – by 2.07% compared to the 7-day-old cheese. Such an increase in the content of polyunsaturated fatty acids in the structure of Alpine cheese occurred due to both *ω*-3 and *ω*-6 PUFA (Table 2). *Ω*-3 polyunsaturated fatty acids in the Alpine cheese are represented only by linolenic acid, the content of which in the fat increased by 0.20% at the 6th month of maturation and by 0.82% at the 12th month of maturation compared to the young cheese. The dynamics of changes in the content of *ω*-3 PUFA in the Alpine cheese was described by a regression line, which had the form of a second-power polynomial (Fig. 1).

Among the *ω*-6 PUFA of Alpine cheese, only linoleic acid was found, the proportion of which increased by 1.41% at the 6th month and by 1.26% at the 12th month of maturity compared to the 7-day-old cheese. The ratio of *ω*-3/*ω*-6 PUFA in the Alpine cheese depended on the maturity period, reaching its maximum at the 6th month and its minimum at the 12th month. Thus, this dependence was nonlinear and expressed by a second-power polynomial (Fig. 1).

The content of DFA and OFA in the fat of the Alpine cheese during the maturity period underwent minor fluctuations, but by the 12th month the desired fatty acids prevailed. At the same time, the dynamics of the IT, H/H, HFI, and IA indices were characterized by a nonlinear dependence on the age of the cheese and were described by a regression line in the form of a second-power polynomial (Fig. 2).

Table 2

Lipid quality of the Alpine cheese made from unpasteurized goat milk during maturity with the participation of *Acarus siro* mites (% of the total fatty acid content) ($x \pm SD$, $n = 5$)

Indicator	Cheese maturity period		
	7 days	6 months	12 months
Σ SFA	68.81 ± 0.21^a	73.64 ± 0.47^b	66.44 ± 0.31^c
Σ UFA	31.19 ± 0.20^a	26.36 ± 0.46^b	33.56 ± 0.29^c
Σ MUFA	28.47 ± 0.15^a	22.05 ± 0.35^b	28.77 ± 0.25^a
Σ PUFA	2.72 ± 0.06^a	4.32 ± 0.21^b	4.79 ± 0.27^c
Σ ω-3 PUFA	0.63 ± 0.03^a	0.83 ± 0.12^b	1.45 ± 0.07^c
Σ ω-6 PUFA	2.08 ± 0.07^a	3.49 ± 0.10^b	3.34 ± 0.23^b
ω-3/ω-6 PUFA	3.30 ± 0.26^a	4.26 ± 0.47^b	2.31 ± 0.15^c
Σ SCFA (4–8)	8.37 ± 0.11^a	10.12 ± 0.36^b	8.97 ± 0.22^c
Σ MCFA (10–16)	46.25 ± 0.07^a	47.14 ± 0.48^b	43.69 ± 0.47^c
Σ LCFA (17–20)	45.38 ± 0.09^a	42.74 ± 0.29^b	47.34 ± 0.46^c
DFA	45.61 ± 0.11^a	42.32 ± 0.29^b	46.95 ± 0.48^c
OFA	35.18 ± 0.21^a	33.65 ± 0.56^b	34.34 ± 0.28^b
Δ^9 desaturase Index (C_{14})	0.056 ± 0.005^a	0.046 ± 0.002^b	0.047 ± 0.004^b
AI	2.03 ± 0.03^a	2.21 ± 0.05^b	1.74 ± 0.04^c
H/H	0.87 ± 0.01^a	0.77 ± 0.02^b	0.96 ± 0.01^c
IT	2.65 ± 0.03^a	2.95 ± 0.14^b	2.11 ± 0.05^c
HFI	0.81 ± 0.01^a	0.72 ± 0.02^b	0.99 ± 0.01^c

Note: superscript letters ^{a,b,c} indicate a probable difference between values in the same row of the table ($P < 0.05$); SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; UFA – unsaturated fatty acids; SCFA – short-chain fatty acids; MCFA – medium-chain fatty acids; LCFA – long-chain fatty acids; DFA – hypocholesterolaemic fatty acids; OFA – hypercholesterolaemic fatty acids; AI – Atherogenicity index; H/H – hypocholesterolaemic/hypercholesterolaemic ratio; IT – hrombogenicity index; HFI – Healthy Fatty Index.

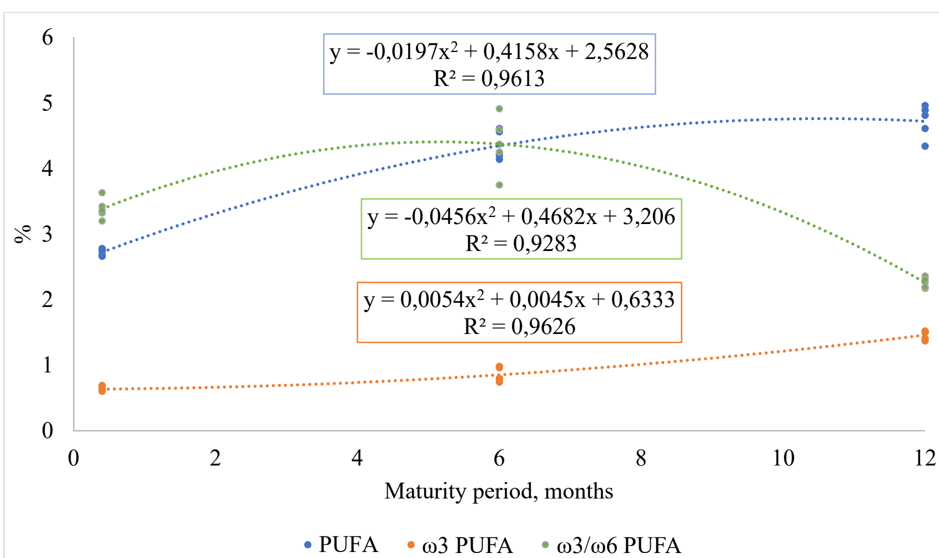

Fig. 1. Dependence of the content of polyunsaturated fatty acids in the Alpine cheese on the maturity period

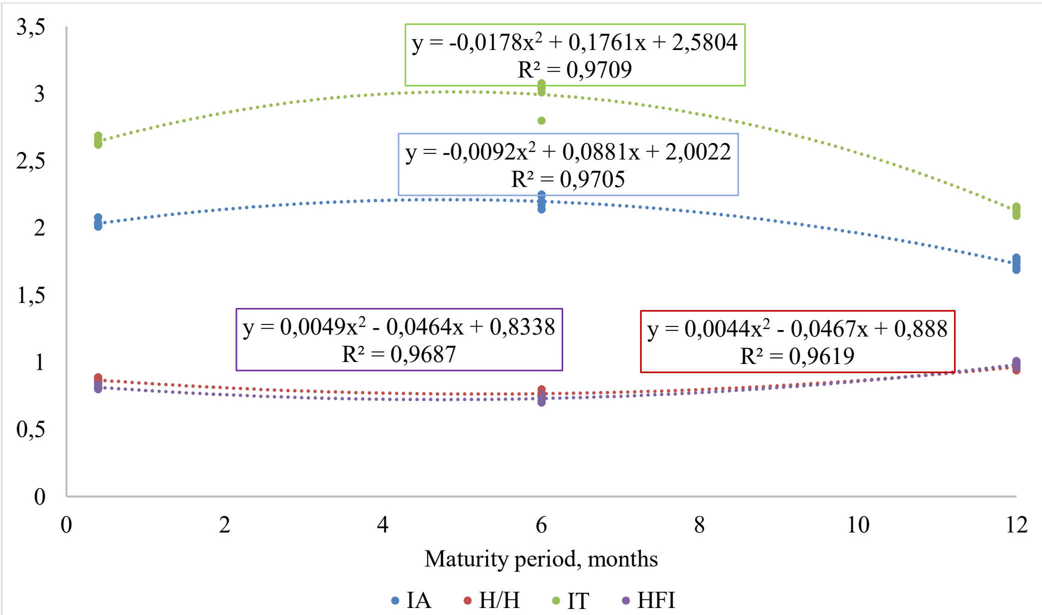

Fig. 2. Dependence of indices of atherogenic, thrombogenic, healthy fat, and the ratio of hypocholesterolemic to hypercholesterolemic fatty acids in the Alpine cheese on the maturity period

The highest values of the IT and IA indices were recorded in mature Alpine cheese aged 6 months, while they were lower in young and old-ripened cheeses. The H/H and HFI indices of the Alpine cheese were characterized by a decrease during the 6-month maturity period and an increase by the 12th month. The Δ^9 desaturase Index (C_{14}) of the Alpine cheese reached a minimum value from the 6th to the 12th month of maturity, which is consistent with the proportions of myristic and myristoleic acids in the structure of its fat (Table 1).

5. 2. Results of investigating the dynamics of the fatty acid composition and lipid quality of the Yogurt cheese

The dynamics in the content of fatty acids in the hard Yogurt cheese differed from the Alpine cheese. In this cheese, the proportion of saturated fatty acids increased by 4.85% at the 6th month and remained within these limits until the 18th month of maturity. Such an increase in the proportion of saturated acids at the 6th month of maturity of the Yogurt cheese occurred to a greater extent due to short-chain fatty acids, in particular butyric, as well as medium-chain ones – hendecanoic, lauric, pentadecanoic, and palmitic. At the 18th month of maturity, the level of saturated fatty acids in the Yogurt cheese was provided by two short-chain acids such as caproic and caprylic, medium-chain – capric and two long-chain – stearic and arachidic (Tables 3, 4).

Accordingly, the proportion of unsaturated fatty acids in the fat structure of the Yogurt cheese was highest at the age of 7 days with a subsequent decrease at the 6th and 18th months of maturity. The decrease in the content of unsaturated fatty acids in the Yogurt cheese during this maturity period was mainly due to monounsaturated fatty acids. Their proportion in the fat of this cheese at the 6th month of maturity decreased by 5.28%, and at the 18th month – by 6.79% compared to the cheese aged 7 days (Table 4).

This dependence of the content of unsaturated fatty acids in the Yogurt cheese was described by a second-power polynomial (Fig. 3).

Table 3

Dynamics of fatty acid content in the Yogurt cheese made from unpasteurized goat milk during maturity with the participation of *Acarus siro* mites (% of the total fatty acid content) ($x \pm SD$, $n = 5$)

Acid	Cheese maturity period		
	7 days	6 months	18 months
Butyric acid, C 4:0	2.64 ± 0.17^{a}	3.89 ± 0.07^{b}	2.37 ± 0.14^{c}
Caproic acid, C 6:0	2.75 ± 0.44^{a}	2.56 ± 0.30^{a}	3.43 ± 0.31^{b}
Caprylic acid, C 8:0	2.83 ± 0.09^{a}	2.71 ± 0.19^{a}	3.92 ± 0.22^{b}
Capric acid, C 10:0	9.43 ± 0.13^{a}	8.64 ± 0.28^{b}	11.29 ± 0.38^{c}
Hendenadecanoic acid, C 11:0	0.26 ± 0.02^{a}	0.43 ± 0.02^{b}	0.15 ± 0.01^{c}
Lauric acid, C 12:0	3.66 ± 0.26^{a}	4.61 ± 0.18^{b}	3.77 ± 0.16^{a}
Myristic acid, C 14:0	9.34 ± 0.15^{a}	8.72 ± 0.13^{b}	7.47 ± 0.19^{c}
Myristoleic acid, C 14:1	0.41 ± 0.03^{a}	0.92 ± 0.05^{b}	0.54 ± 0.03^{c}
Pentadecanoic acid, C 15:0	0.61 ± 0.04^{a}	0.97 ± 0.07^{b}	0.74 ± 0.06^{c}
Palmitic acid, C 16:0	22.02 ± 0.50^{a}	24.02 ± 0.29^{b}	24.44 ± 0.46^{a}
Stearic acid, C 18:0	14.28 ± 0.76^{a}	14.98 ± 0.38^{a}	16.86 ± 0.20^{b}
Oleic acid, C 18:1n9c	28.46 ± 0.26^{a}	22.66 ± 0.15^{b}	21.54 ± 0.55^{c}
Linoleic acid, C 18:2n6c	2.24 ± 0.19^{a}	3.30 ± 0.23^{b}	3.68 ± 0.11^{c}
Arachidic acid, C 20:0	0.47 ± 0.14^{a}	0.79 ± 0.02^{b}	1.28 ± 0.05^{c}
Linolenic acid, C 18:3n3	0.63 ± 0.02^{a}	0.81 ± 0.04^{b}	1.55 ± 0.07^{c}

Note: superscript letters $^{a, b, c}$ indicate a probable difference between values in the same row of the table ($P < 0.05$).

Despite the increase in the content of myristoleic acid, the main contribution to the decrease in the total proportion of monounsaturated acids during the maturity period of the Yogurt cheese was made by oleic acid. Similar to the Alpine cheese, an increase in the content of polyunsaturated fatty acids was noted in the Yogurt cheese with an increase in the maturity period. It was found that at the age of 6 months, the proportion of PUFA in the fat structure of the Yogurt cheese increased by 1.24%, and at the 18th month – by 2.35% compared to young cheese aged 7 days (Table 4). The dependence of the content of polyunsaturated fatty acids on the maturity period of the Yogurt cheese was nonlinear and was expressed by a second-power polynomial (Fig. 3). Such an increase in the proportion of PUFA in the fat of the Yogurt cheese is associated with an increase in the content of both ω-3 and ω-6 PUFA. As in the Alpine cheese, in the Yogurt cheese, the representatives of ω-3 and ω-6 PUFA were the same, and the dependence of their content on the duration of cheese maturity was expressed by a second-power polynomial (Fig. 4).

At the same time, the ratio of ω-3/ω-6 PUFA in this cheese was characterized by relative stability from the 7th day to the 6th month, and at the 18th month of maturity, a decrease in this value by 1.19 was noted.

The content of desirable (hypocholesterolemic) acids (DFA) in the Yogurt cheese reached its peak on the 7th day of maturity, decreasing throughout the maturity period. At the same time, the proportion of hypercholesterolemic acids (OFA) in the structure of its fat reached its maximum content on the 6th month with a subsequent decrease on the 18th month of maturity. A similar pattern was noted in the dynamics of the Δ^9 desaturase Index (C_{14}) of the Yogurt cheese, which corresponded to fluctuations in the content of myristic and myristoleic acids during these maturity periods.

The IT of the Yogurt cheese during the maturity period was characterized by dynamics similar to the Δ^9 desaturase Index (C_{14}). A somewhat reverse trend was observed for the H/H and HFI indices, which in the Yogurt cheese decreased by the 6th month, and then increased by the 18th month of maturity and reached almost the initial value. Such a dependence of the indices in the Yogurt cheese in all cases was described by a regression line in the form of a second-power polynomial (Fig. 5).

Our research results indicate that the dynamics of individual milk fat quality indices of the Yogurt cheese coincide, in particular Δ^9 desaturase Index (C_{14}) and IT, as well as H/H and HFI.

Table 4

Lipid quality of the Yogurt cheese made from unpasteurized goat milk during maturity with the participation of *Acarus siro* mites (% of the total fatty acid content) ($x \pm SD$, $n = 5$)

Indicator	Cheese maturity period		
	7 days	6 months	18 months
Σ SFA	68.27 ± 0.34^a	72.32 ± 0.26^b	72.71 ± 0.44^b
Σ UFA	31.73 ± 0.32^a	27.68 ± 0.27^b	27.29 ± 0.43^b
Σ MUFA	28.86 ± 0.28^a	23.58 ± 0.13^b	22.07 ± 0.57^c
Σ PUFA	2.87 ± 0.18^a	4.11 ± 0.20^b	5.22 ± 0.16^c
Σ ω-3 PUFA	0.63 ± 0.02^a	0.81 ± 0.04^b	1.55 ± 0.07^c
Σ ω-6 PUFA	2.24 ± 0.19^a	3.30 ± 0.23^b	3.68 ± 0.11^c
ω-3/ω-6 PUFA	3.57 ± 0.40^a	4.11 ± 0.44^a	2.38 ± 0.09^b
Σ SCFA (4–8)	8.21 ± 0.42^a	9.16 ± 0.52^b	9.72 ± 0.37^b
Σ MCFA (10–16)	45.71 ± 0.50^a	48.31 ± 0.47^b	45.39 ± 0.31^a
Σ LCFA (17–20)	46.08 ± 0.52^a	42.52 ± 0.65^b	44.90 ± 0.41^c
DFA	46.02 ± 0.61^a	42.66 ± 0.63^b	44.15 ± 0.45^c
OFA	35.01 ± 0.39^a	37.35 ± 0.19^b	32.68 ± 0.30^c
Δ^9 desaturase Index (C_{14})	0.042 ± 0.003^a	0.096 ± 0.004^b	0.067 ± 0.005^c
AI	1.99 ± 0.02^a	2.29 ± 0.03^b	2.02 ± 0.05^a
H/H	0.89 ± 0.01^a	0.72 ± 0.02^b	0.82 ± 0.03^c
IT	2.58 ± 0.03^a	2.95 ± 0.14^b	2.11 ± 0.05^c
HFI	0.83 ± 0.01^a	0.75 ± 0.01^b	0.82 ± 0.02^a

Note: superscript letters $^{a, b, c}$ indicate a probable difference between values in the same row of the table ($P < 0.05$); SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; UFA – unsaturated fatty acids; SCFA – short-chain fatty acids; MCFA – medium-chain fatty acids; LCFA – long-chain fatty acids; DFA – hypocholesterolaemic fatty acids; OFA – hypercholesterolaemic fatty acids; AI – Atherogenicity index; H/H – hypocholesterolaemic/hypercholesterolaemic ratio; IT – thrombogenicity index; HFI – Healthy Fatty Index.

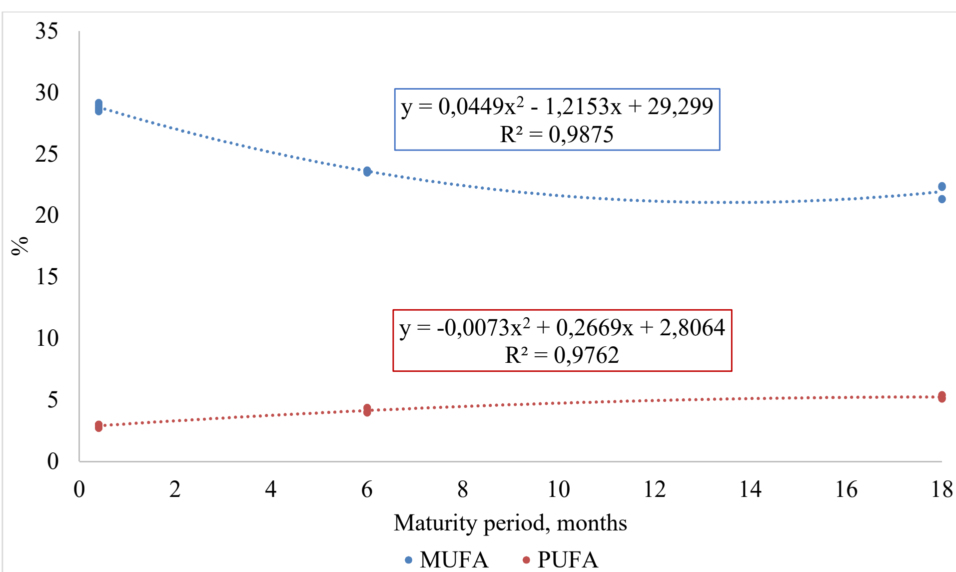

Fig. 3. Dependence of the content of monounsaturated and polyunsaturated fatty acids in the Yogurt cheese on the maturity period

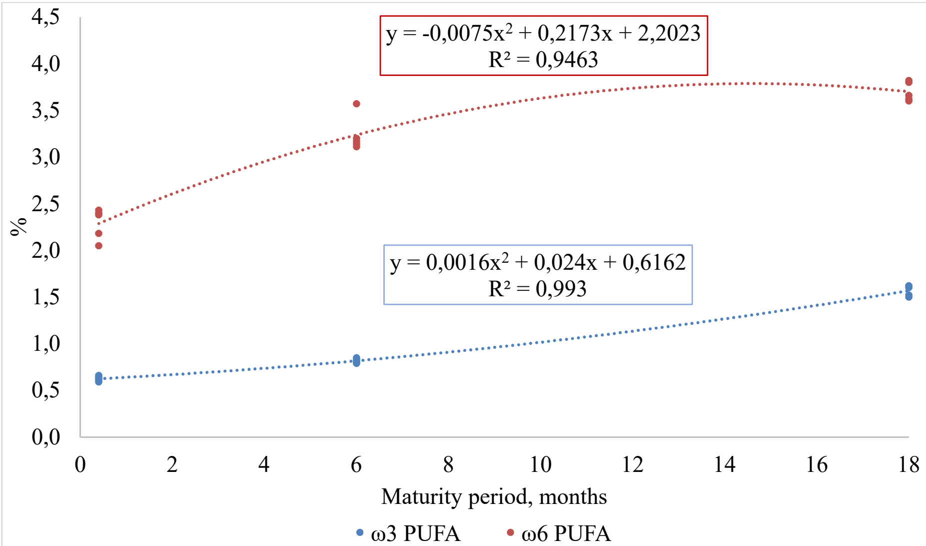

Fig. 4. Dependence of the content of polyunsaturated fatty acids in the Yogurt cheese on the maturity period

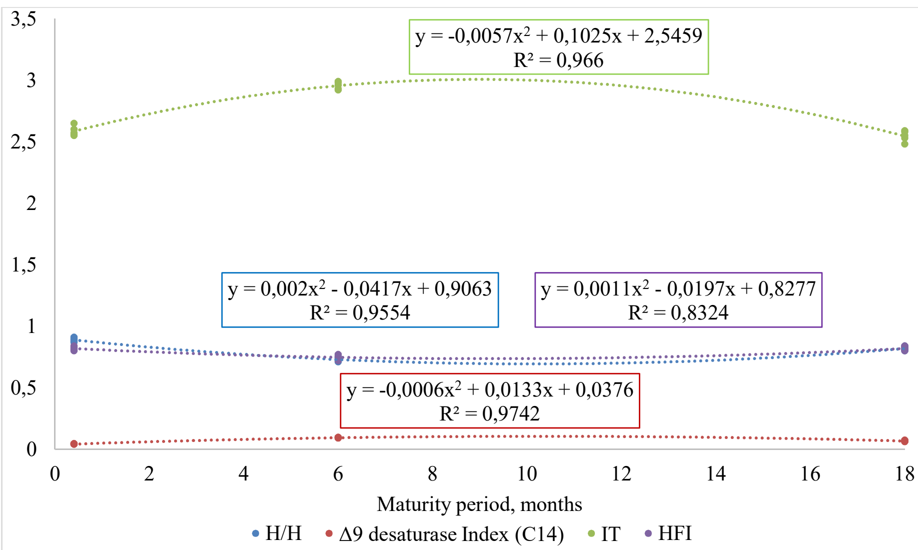

Fig. 5. Dependence of Δ^9 desaturase (C_{14}), thrombogenic, healthy fat indices and the ratio of hypocholesterolemic to hypercholesterolemic fatty acids in the Yogurt cheese on the maturity period

6. Results of investigating the fatty acid composition and lipid quality of the Alpine and Yogurt cheeses: discussion and summary

The fat of goat cheeses can contain 38 fatty acids, of which 20 are saturated, 9 are monounsaturated, and 9 are polyunsaturated. As a rule, the basis of fatty acids is 8, which corresponds to 91% of the total content, in particular C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C18:1, and C18:2 [20]. In contrast, in this study, only 15 fatty acids were found in the hard goat cheeses Alpine and Yogurt made from unpasteurized milk (Tables 1, 3). The main saturated fatty acids were myristic, palmitic, and stearic. The basis of unsaturated acids in the Alpine and Yogurt cheeses was oleic, which is associated with the peculiarities of the composition of milk fat of ruminants and is consistent with other studies on goat cheeses [24]. Similar results were obtained in [25] when analyzing Graviera cheese made from pasteurized and unpasteurized cow's milk. In the cited study, as well as in other studies on Casseri and Graviera cheeses, it was found that palmitic acid in hard cow's milk cheeses dominated the other acids, and its content exceeded 35%. In contrast, when analyzing the hard goat cheeses Alpine and Yogurt, the dominance of monounsaturated oleic acid was revealed throughout their maturity period. The proportion of palmitic acid in both cheeses fluctuated without a certain pattern throughout the maturity period (Tables 1, 3), although in comparison with Graviera cheese made from both pasteurized and unpasteurized milk, its decrease was found with an increase in the maturity period up to 120 days. Cheddar cheese made from standardized cow's milk during 5 months of maturity also showed a higher palmitic acid content, reaching 27.2%, and oleic acid level – 24.4% [26].

The Alpine and Yogurt goat cheeses in terms of the content of short- and medium-chain acids such as butyric, caproic, caprylic, and capric (Tables 2, 4) were superior to Graviera cheese from cow's milk [25] but were as close as possible to Caciotta and Canestrato cheeses from goat's milk [24]. This may be due to the peculiarities of the composition of milk fat of different ruminants, their breed, feeding ration, physiological state, season of production and maintenance [27], as well as the recipe and maturity period of the cheeses [28]. Such a difference in the content of short- and medium-chain fatty acids between goat and cow cheeses is explained by the specifics of the pronounced bright "goat" taste, which is formed due to the predominance of caproic, caprylic, and capric acids in the lipids of the milk of these animals.

Myristic acid (C14:0) was found in high concentrations in the Alpine and Yogurt cheeses, but its content decreased with increasing age in both cases (Tables 1, 3). The Yogurt cheese was characterized by an increase in the proportion of myristoleic acid with increasing maturity time, which was consistent with the Δ^9desaturase Index (C_{14}), but no such pattern was found for the Alpine cheese (Tables 2, 4).

The dynamics in the content of stearic acid (C18:0) as one of the main saturated acids in the Yogurt cheese was inversely proportional to the maturity time, but this was not characteristic of the Alpine cheese. At the same time, the proportion of stearic acid in both goat cheeses significantly exceeded the similar indicator of Graviera cheeses from cow's milk [25], while these cheeses were close in terms of the content of lauric acid.

Most polyunsaturated fatty acids that have one or more double bonds, in particular linoleic and linolenic, must enter the human body through the alimentary route, in particular with products that contain a lot of fat. At the same time, there is an imbalance of polyunsaturated fatty acids in the current human diet, which is associated with an excessive intake of ω-6 PUFA and a deficiency of ω-3 PUFA. Such a diet provokes chronic pathology, which can be complicated by obesity. Among animal-derived foods, dairy products are prioritized, namely cheeses in which the ratio of polyunsaturated fatty acids is as close as possible to the desired one [24].

A feature of the Alpine and Yogurt goat cheeses made from unpasteurized milk was the direct dependence of the content of linoleic acid (ω-6), and linolenic acid – the only ω-3 polyunsaturated acid, on the term of their maturity. This is consistent with similar data obtained from the analysis of Gravier cheeses made from pasteurized and unpasteurized cow's milk [25]. The significant accumulation of linoleic acid during the maturity period of the Alpine and Yogurt cheeses made from unpasteurized goat's milk could be associated with the ability of certain strains of lactic acid bacteria to synthesize linoleic acid isomerase. Such microorganisms include *Lactiplantibacillus plantarum* [28, 29], which was detected in the Alpine goat's cheese, while in the Yogurt cheese other lactic acid bacteria could be possible producers of this enzyme. This, in turn, ensured the formation of the uniqueness of the texture and biological value of such cheeses [30].

Among the indicators of milk fat quality, it is important to take into account the absolute amount of individual polyunsaturated fatty acids, as well as the ratio of ω-3/ω-6 PUFA, which in the human diet should fluctuate within 1:1–1:4. In the Alpine and Yogurt cheeses, it did not exceed the upper limit of the optimal value and decreased upon reaching the age of 12 and 18 months, respectively (Fig. 1, 3, 4), which is consistent with previously conducted studies on other hard goat cheeses [24].

The dynamics of hypocholesterolemic (desirable) fatty acids in the Alpine and Yogurt cheeses in all cases exceeded the proportion of hypercholesterolemic ones (Tables 2, 4). The milk fat quality indices of both hard cheeses Alpine and Yogurt were similar in general trend during the maturity process (Fig. 2, 5). It is worth noting that the atherogenicity and thrombogenicity indices in both cheeses practically reflected the same pattern, that is, their dynamics were characterized by a certain synchrony. The same pattern was found for the H/H and HFI indices. At the same time, the dynamics of the healthy fat index actually overlapped the index of the ratio of hypocholesterolemic to hypercholesterolemic acids. Thus, in the case of analyzing the fat quality of hard goat cheeses from unpasteurized goat milk of long maturity, the H/H and HFI indices duplicated each other.

Comparison of the lipid quality of the hard goat cheeses Alpine and Yogurt with other cheeses showed that in terms of healthy fat index, both cheeses were inferior to aged cheese, Mix Caciotta, Ricotta made from cow and sheep milk, and Creamy Blue Cheese. The atherogenic index of the Alpine and Yogurt cheeses was significantly lower compared to the above-listed cheeses, with the exception of Creamy Blue Cheese. In terms of thrombogenicity index, they were close to all of the above-listed cheeses, inferior only to Creamy Blue Cheese [23].

One of the most important criteria for assessing the lipids of food products is comparing their quality with a product that a person produces for a person, that is, breast milk. Breast milk was characterized by an atherogenic index (AI) of 1.47, a thrombogenic index (TI) of 1.60, and a ratio of hypocholesterolemic to hypercholesterolemic acids (H/H) of 1.21 [31]. The lipids of the Alpine and Yogurt cheeses were somewhat inferior to breast milk in the above indices. This may be due to the long period of their maturation and the participation of a significant number of species of microorganisms, fungi, yeasts, and acarid mites in this process [16].

Therefore, to devise a criterion for assessing the quality, safety, age, and authenticity of craft hard cheeses from unpasteurized goat milk, the ratio of fatty acids and milk fat quality indices could be used.

The limitation of our study was determining the fatty acid composition of hard cheeses without taking into account the fatty acid composition of goat milk. The lack of sensory evaluation of hard cheeses during maturity can be considered a disadvantage of our work. An instrumental analysis of the aromatic composition of hard cheeses from unpasteurized goat milk during maturity is promising. This study may be advanced through the microstructural analysis of hard goat cheeses during maturity. This would complement and expand the composition of the comprehensive criterion for their evaluation.

7. Conclusion

1. It has been established that during the maturity period, 15 fatty acids were detected in the Alpine cheese: 3 short-chain (butyric, caproic, and caprylic), 7 medium-chain (hendecanoic, lauric, myristic, myristoleic, pentadecanoic, and palmitic), and 5 long-chain (stearic, oleic, linoleic, linolenic, and arachidic). The main fatty acid of the lipids of this cheese was monounsaturated – oleic, its content ranged within 21.65–28.37%. Among saturated acids, palmitic acid took the largest share in the structure of milk fat. Polyunsaturated acids consisted of the sum of linoleic and linolenic acids, the content of which in lipids increased throughout the maturity period of Alpine cheese from 2.72% to 4.79%. Among the milk fat quality indicators, the highest values of the IT and IA indices were characteristic of this cheese with a maturity period of 6 months and were characterized by a decrease until the age of 12 months. During the same period, the H/H and HFI indices reached a minimum value with a subsequent increase upon reaching the age of 12 months. The Δ^9 desaturase Index (C_{14}) of the fat decreased by the 6th month of maturity and stabilized at this level until the 12th month. Our results regarding the fatty acid composition of the Alpine cheese reflect its difference from other cheeses of a similar type in a unique ratio of fatty acids and high quality lipids. This is due to the breed of goats, feeding and grazing conditions, as well as the geographical location of the area.

2. The fatty acid composition of lipids of the Yogurt cheese coincided with the Alpine cheese during the maturity period, which is due to the use of the same raw material – milk for their manufacture. At the same time, the dynamics of the fatty acid composition and quality of lipids of the Yogurt cheese differed from the Alpine cheese, which is explained

by the different technology of their manufacture. The content of oleic acid in the Yogurt cheese was characterized by an inverse dependence on the maturity period and fluctuated within 21.54–28.46%. The proportion of polyunsaturated fatty acids in the lipids of this cheese increased in direct proportion to its age from 2.87% to 5.22%. The content of unsaturated fatty acids in the Yogurt cheese was characterized by a decrease at the age of 6 and 18 months by 4.05% and 4.44%, respectively, which was consistent with a decrease in the proportion of monounsaturated fatty acids, in particular oleic. The content of hypocholesterolemic acids (DFA) in the Yogurt cheese during the maturity period decreased against the background of an increase in Δ^9 desaturase Index (C_{14}). IT and IA of the Yogurt cheese reached peak values at the age of 6 months, and young and old-ripened cheeses had better indicators. According to the H/H and HFI indices, the fat quality of the Yogurt cheese was the best at the age of 7 days and 12 months. Craft hard Yogurt cheese belongs to authentic cheeses, which makes it unique not only in its fatty acid composition and provides high quality lipids but also in its health benefits for consumers.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

Funding

The study was conducted without financial support.

Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

Authors' contributions

Viktor Davydovych: Conceptualization, Methodology, Investigation; **Larysa Shevchenko**: Conceptualization, Management, Project administration; **Natalia Slobodyanyuk**: Methodology, Validation, Data curation; **Svitlana Furman**: Methodology, Writing – original draft; **Valentyna Bandura**: Writing – original draft, Formal analysis, Visualization; **Tetiana Lebedenko**: Resources, Writing – review & editing; **Olena Sydorenko**: Formal analysis; **Nataliia Kovalenko**: Validation; **Natalia Nesterenko**: Resources.

References

1. Inácio, R. S., Rodríguez-Alcalá, L. M., Pimentel, L. L., Saraiva, J. A., Gomes, A. M. P. (2023). Evolution of Qualitative and Quantitative Lipid Profiles of High-Pressure-Processed Serra da Estrela Cheese throughout Storage. Applied Sciences, 13 (10), 5927. https://doi.org/10.3390/app13105927
2. 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
3. Kasapidou, E., Karatzia, M.-A., Mitlianga, P., Basdagianni, Z. (2022). Effects of Production Systems and Seasons on Retail-Goat-Milk Fatty-Acid Composition and Nutritional Indices in Greece. Animals, 12 (17), 2204. https://doi.org/10.3390/ani12172204
4. Bal-Prylypko, L., Nikolaenko, M., Volkhova, T., Holembovska, N., Tyshchenko, L., Ivaniuta, A. et al. (2023). The study of functional and technological properties of vegetarian ice cream. Potravinarstvo Slovak Journal of Food Sciences, 17, 110–121. https://doi.org/10.5219/1798
5. Vlasenko, I., Bandura, V., Semko, T., Fialkovska, L., Ivanishcheva, O., Palamarchuk, V. (2021). Innovative approaches to the development of a new sour milk product. Potravinarstvo Slovak Journal of Food Sciences, 15, 970–981. https://doi.org/10.5219/1688
6. Savchenko, O., Grek, O., Skuibida, V., Onopriichuk, O., Pshenychna, T. (2025). Optimisation of parameters for obtaining milk-plant concentrates. Animal Science and Food Technology, 16 (1), 126–140. https://doi.org/10.31548/animal.1.2025.126
7. Davydovych, V., Shevchenko, L., Shulyak, S., Nedashkivskyi, V., Semenko, O., Tyshchenko, L. et al. (2025). Influence of aging time on the physicochemical characteristics of craft soft cheeses made from unpasteurized goat's milk. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 73 (4-5), 243–252. https://doi.org/10.11118/actaun.2025.017
8. Ali, A. H., Khalifa, S. A., Gan, R.-Y., Shah, N., Ayyash, M. (2023). Fatty acids, lipid quality parameters, and amino acid profiles of unripened and ripened cheeses produced from different milk sources. Journal of Food Composition and Analysis, 123, 105588. https://doi.org/10.1016/j.jfca.2023.105588
9. Anedda, R., Pardu, A., Korb, J.-P., Curti, E. (2021). Effect of the manufacturing process on Fiore Sardo PDO cheese microstructure by multi-frequency NMR relaxometry. Food Research International, 140, 110079. https://doi.org/10.1016/j.foodres.2020.110079
10. Iakubchak, O., Martynenko, O., Taran, T., Pylypchuk, O., Naumenko, T., Tverezovska, N. et al. (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
11. Wang, F., Wang, M., Xu, L., Qian, J., Xu, B., Gao, X. et al. (2025). Application and Possible Mechanism of Microbial Fermentation and Enzyme Catalysis in Regulation of Food Flavour. Foods, 14 (11), 1909. https://doi.org/10.3390/foods14111909
12. Westheim, A. J. F., Stoffels, L. M., Dubois, L. J., van Bergenhenegouwen, J., van Helvoort, A., Langen, R. C. J. et al. (2022). Fatty Acids as a Tool to Boost Cancer Immunotherapy Efficacy. Frontiers in Nutrition, 9. https://doi.org/10.3389/fnut.2022.868436

13. Kapoor, B., Kapoor, D., Gautam, S., Singh, R., Bhardwaj, S. (2021). Dietary Polyunsaturated Fatty Acids (PUFAs): Uses and Potential Health Benefits. Current Nutrition Reports, 10 (3), 232–242. https://doi.org/10.1007/s13668-021-00363-3
14. Barać, M. (2025). Fatty acid profiles and health fatty acid indices of traditional cheeses of southeastern European countries. Mljekarstvo, 75 (2), 63–77. https://doi.org/10.15567/mljekarstvo.2025.0201
15. Bittante, G., Amalfitano, N., Tagliapietra, F., Schiavon, S., Cipolat-Gotet, C., Stocco, G. (2024). Characterization of the Detailed Fatty Acid Profiles of a Large Number of Types of Cheese from the Mountains and Plains. Foods, 13 (24), 4040. https://doi.org/10.3390/foods13244040
16. Davydovych, V., Shevchenko, L., Brovenko, T., Nesterenko, N., Altanova, A., Umanets, R. et al. (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
17. Folch, J., Lees, M., Stanley, G. H. S. (1957). A simple method for the isolation and purification of total lipides from animal tissues. Journal of Biological Chemistry, 226 (1), 497–509. https://doi.org/10.1016/s0021-9258(18)64849-5
18. Christie, W. W. (1982). Lipid analysis: isolation, separation, identification, and structural analysis of lipids. Pergamon Press.
19. Burgos, L. S., Pece, N., Maldonado, S. (2020). Fatty acid composition and microstructure of ripened goat cheese. Latin American Applied Research - An International Journal, 51 (1), 43–48. https://doi.org/10.52292/j.laar.2021.166
20. Medeiros, E., Queiroga, R., Oliveira, M., Medeiros, A., Sabedot, M., Bomfim, M., Madruga, M. (2014). Fatty Acid Profile of Cheese from Dairy Goats Fed a Diet Enriched with Castor, Sesame and Faveleira Vegetable Oils. Molecules, 19 (1), 992–1003. https://doi.org/10.3390/molecules19010992
21. Ivanova, A., Hadzhinikolova, L. (2015). Evaluation of nutritional quality of common carp (Cyprinus carpio L.) lipids through fatty acid ratios and lipid indices. Bulgarian Journal of Agricultural Science, 21 (1). 180–185. Available at: https://www.agrojournal.org/21/01s-27.pdf
22. Ulbricht, T. L. V., Southgate, D. A. T. (1991). Coronary heart disease: seven dietary factors. The Lancet, 338 (8773), 985–992. https://doi.org/10.1016/0140-6736(91)91846-m
23. Dal Bosco, A., Cavallo, M., Menchetti, L., Angelucci, E., Cartoni Mancinelli, A., Vaudo, G. et al. (2024). The Healthy Fatty Index Allows for Deeper Insights into the Lipid Composition of Foods of Animal Origin When Compared with the Atherogenic and Thrombogenicity Indexes. Foods, 13 (10), 1568. https://doi.org/10.3390/foods13101568
24. Sadvari, V. Y., Shevchenko, L. V., Midyk, S. V., Korniyenko, V. I., Slobodyanyuk, N. M., Pylypchuk, O. S. et al. (2025). Fatty acid profile of artisanal hard cheeses made from raw goat milk during the ripening process. Regulatory Mechanisms in Biosystems, 33 (1), e25002. https://doi.org/10.15421/0225002
25. Ioannidou, M. D., Maggira, M., Samouris, G. (2022). Physicochemical Characteristics, Fatty Acids Profile and Lipid Oxidation during Ripening of Graviera Cheese Produced with Raw and Pasteurized Milk. Foods, 11 (14), 2138. https://doi.org/10.3390/foods11142138
26. Singh, T. P., Arora, S., Borad, S. G., Bam, J., Paul, V., Thomas, R., Sarkar, M. (2023). Fatty acid and amino acid profiling, antioxidant activity and other quality characteristics of vacuum packed cheddar style-yak milk cheese during ripening. Food Bioscience, 51, 102213. https://doi.org/10.1016/j.fbio.2022.102213
27. Mylostyvyi, R., Midyk, S., Izhboldina, O., Cherniy, N., Kornienko, V. (2023). Changes in the Qualitative Composition of the milk of Holstein Cows During Summer Chronic Heat Stress. Jurnal Ilmu Ternak Dan Veteriner, 28 (2), 112–121. https://doi.org/10.14334/jitv.v28i2.3151
28. Sadvari, V. Y., Shevchenko, L. V., Slobodyanyuk, N. M., Tupitska, O. M., Gruntkovskyi, 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
29. Davydovych, V., Shevchenko, L., Mykhalska, V., Pylypchuk, O., Naumenko, T. (2025). Microbiome of Kraft soft cheeses made from raw goat milk during ripening. Animal Science and Food Technology, 16 (3), 105–120. https://doi.org/10.31548/animal.3.2025.105
30. Davydovych, V., Shevchenko, L., Shulyak, S., Slobodyanyuk, N., Nedashkivskyi, V., Tomchuk, V. et al. (2025). The influence of ripening time on the physicochemical characteristics of craft hard goat cheeses. Online Journal of Animal and Feed Research, 15 (5), 264–273. https://doi.org/10.51227/ojafr.2025.30
31. Purkiewicz, A., Pietrzak-Fiećko, R. (2024). Determination of the Fatty Acid Profile and Lipid Quality Indices in Selected Infant Formulas. Molecules, 29 (9), 2044. https://doi.org/10.3390/molecules29092044