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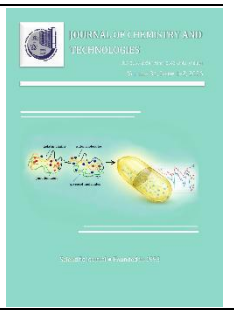

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INFLUENCE OF RIP-ENING TIME ON THE FATTY ACIDS PROFILE AND LIPID QUALITY OF SOFT CHEESES MADE FROM UNPASTEURISED GOAT`S MILK

Viktor A. Davydovych, Larysa V. Shevchenko, Svitlana V. Midyk, Serhii V. Boiarchuk, Ivan M. Cheverda, Valentyna M. Israelian, Gennadii F. Tkach, Yevheniia I. Marchyshyna, Alina M. Omelian

National University of Life and Environmental Sciences of Ukraine, Heroiiv Oborony St., 15, Kyiv, 03041, Ukraine

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Abstract

Expanding the range of artisanal soft cheeses made from unpasteurised goat's milk on the food market meets consumer demand for healthy nutrition and requires the development of criteria for assessing their quality, biological value, age, and authenticity. This involves determining the dynamics of their fatty acid composition and the quality of milk fat during the ripening process. The experiment used artisanal brine Feta cheese with a ripening period of 30 months and artisanal Chevre cheese with white noble mould with a ripening period of 40 days, made at one of the eco-enterprises of the Kyiv region (Ukraine). The study was conducted from May 2022 to December 2024 using gas chromatography. 15 fatty acids were detected in Feta and Chevre cheeses, of which 11 were saturated and 4 were unsaturated. The basis of saturated fatty acids in Chevre and Feta cheeses was palmitic, stearic, capric, and myristic. The proportion of oleic acid in Feta cheese was inversely correlated with the ripening period (r = –0.920 ± 0.074, P < 0.001). The value of ω3/ω6 PUFA during the ripening period varied for Feta cheese within the range of 1 : 4.96–5.74 and for Chevre cheese – 1 : 4.47–43.16. A distinctive feature of Chevre cheese was an increase in the content of linolenic acid by 0.88–0.94% and linoleic acid by 0.73–1.21% on the 40th day of ripening. According to fat quality indicators, Feta cheese was characterized by the highest dietary properties from the 7th day to the 18th month of ripening, and cheese Chevre - on the 40th day of ripening. The fatty acid profile of artisanal goat cheeses Feta and Chevre can be used as one of the criteria for assessing their age and authenticity in combination with physicochemical and microbiological indicators.

Keywords: Feta; Chevre; saturated and polyunsaturated fatty acids; index of atherogenicity; index of thrombogenicity; healthy fatty index.

ВПЛИВ ТЕРМІНУ ДОЗРІВАННЯ НА СКЛАД ЖИРНИХ КИСЛОТ ТА ЯКІСТЬ ЛІПІДІВ У М'ЯКИХ СИРАХ, ВИГОТОВЛЕНИХ З НЕПАСТЕРИЗОВАНОГО КОЗЯЧОГО МОЛОКА

Віктор А. Давидович, Лариса В. Шевченко, Світлана В. Мидик, Сергій В. Боярчук, Іван М. Чеверда, Валентина М. Ізраїлян, Геннадій Ф. Ткач, Євгенія І. Марчишина, Аліна М. Омелян

Національний університет життя та екологічних наук України, вул. Героїв Оборони, 15, Київ, 03041, Україна

Анотація

Розширення асортименту м’яких сирів крафтового виробництва з непастеризованого козиного молока на ринку харчових продуктів відповідає споживчому попиту на здорове харчування та вимагає розробки критеріїв оцінки їхньої якості, біологічної цінності, віку та автентичності. Для експериментів використовували крафтовий розсільний сир Фета з терміном дозрівання 30 місяців та сир Шевр з білою благородною пліснявою й терміном дозрівання 40 днів, виготовлені на одному з екопідприємств Київської області (Україна). Дослідження проводили з травня 2022 року по грудень 2024 року з використанням газової хроматографії. У сирах Фета та Шевр виявлено 15 жирних кислот, з яких 11 були насиченими та 4 – ненасиченими. Основу насичених жирних кислот сирів Шевр і Фета складали пальмітинова, стеаринова, капринова та міристинова. Частка олеїнової кислоти в сирі Фета обернено корелювала з терміном дозрівання (r = –0.920 ± 0.074, P < 0.001). Значення ω3/ω6 ПНЖК протягом періоду дозрівання змінювалося для сиру Фета в діапазоні 1 : 4.96–5.74, а для сиру Шевр – 1 : 4.47–43.16. Відмінною особливістю сиру Шевр було збільшення вмісту ліноленової кислоти на 0.88–0.94 % та лінолевої кислоти на 0.73–1.21 % на 40-й день дозрівання. За показниками якості жиру сир Фета характеризувався найвищими дієтичними властивостями з 7-го дня до 18-го місяця дозрівання, а сир Шевр – на 40-й день дозрівання. Жирнокислотний профіль крафтових козиних сирів Фета та Шевр можна використовувати як один із критеріїв оцінки їхнього віку та автентичності в поєднанні з фізико-хімічними та мікробіологічними показниками.

Ключові слова: Фета; Шевр; насичені і поліненасичені жирні кислоти; індекс атерогенності; індекс тромбогенності; індекс здорового жиру.

**Corresponding author: e-mail: israelyan@nubip.edu.ua*
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Introduction

Dairy products, in particular cheeses, are among the foods with high dietary properties. Cheeses are a source of nutrients and biologically active substances, in particular proteins, lipids, mineral components and vitamins for the human body. In addition, milk fat forms not only the nutritional value but also the structural, taste and aromatic characteristics of cheeses [1; 2]. This also contributes to the continual expansion of their range within the food products market, particularly cheeses with functional properties [3]. Modern consumers are in conditions of wide availability of information about the quality and safety of food products, which allows them to choose producers with a high level of trust [4; 5]. This is facilitated by the implementation of the One Health concept and the development of environmentally friendly technologies.

Industrial technologies for the production of cheeses from ruminant milk involve multi-stage processing and pasteurisation of raw materials, which, on the one hand, ensures the destruction of pathogenic microorganisms [6] and, on the other hand, significantly worsens the sensory characteristics of the finished product. Therefore, interest in the production of artisanal cheeses from unpasteurised milk, in particular goat`s milk, is growing every year. This allows for the shortening of the dairy supply chain and a reduction in the ecological load by reducing the concentration of livestock in production areas, as well as producing authentic products such as cheeses with unique taste characteristics [7], which are formed due to the rich fatty acid composition of goat unpasteurised milk. Of particular interest to consumers in this regard are brine cheeses, such as Feta, and cheeses ripened with the participation of noble mould, such as Camembert or Brie. They are produced worldwide in significant quantities and have recently gained wide popularity in Ukraine due to the expansion of artisanal production of goat dairy products.

The content and ratio of fatty acids in dairy products, particularly cheeses, has aroused and continues to arouse increased interest among consumers regarding their impact on health. The milk fat of ruminants contains about 400 fatty acids, more than half of which are saturated acids [8; 9]. The high fat content of cheeses is the cause of scientific discussions regarding the benefits of its individual components for the human body, in particular fatty acids such as myristic and palmitic acids, which can increase blood cholesterol levels and provoke the development of coronary heart disease [1].

In addition to hypercholesterolemic, cheeses contain a number of beneficial fatty acids that contribute to human health. These include unsaturated fatty acids, in particular linoleic, vaccenic, α-linolenic and oleic. In general, fatty acids with a carbon chain of C4:0–C12:0 are considered beneficial for the human body since they are able to reduce body weight in cases of obesity [8]. A link has also been proven between the concentration of short- and medium-chain fatty acids, in particular caproic, capric, and lauric acids, and obesity in children and adults [10].

Fatty acids in dairy products can not only help correct various metabolic disorders but also have a protective and immunomodulatory effect in the long term [11]. Long-chain fatty acids have cytotoxicity for cancer cells, anti-inflammatory effects, stimulate the reduction of serum lipid levels, and maintain the sensitivity of target cells to insulin [12].

In addition to their dietary properties, lauric and capric acids exhibit a bactericidal effect against foodborne pathogens, in particular *Listeria monocytogenes*, *Salmonella enteritidis, Clostridium perfringens*, *C. difficile, Campylobacter jejuni* and *Escherichia coli* [13–15].

Soft cheeses such as Camembert and Feta, made from cow's, sheep's, goat's or blends of milk from different animal species, have been studied for their fatty acid content and lipid quality, which has shown their positive effect on human metabolism [1]. Cheeses made from the milk of small ruminants, due to the high content of short-chain and polyunsaturated fatty acids, are characterised by bright original taste properties, which provide them with an honourable place among elite food products [16]. This, in turn, involves their certification, determination of authenticity, ripening (storage) period, quality indicators and safety, which is often problematic for artisanal production and causes a certain distrust of consumers.

It is believed that the fatty acid composition of cheeses can contribute to the certification of origin, improve the transparency of the finished product supply chain and increase consumer demand. Fatty acids in cheeses are biochemical markers of regional products that have a geographical origin and reflect the specifics of feeding, grazing or breed of dairy cattle [17], which allows to form not only high demand but also additional market value and authentication criteria for such dairy products [18].

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As for artisanal soft cheeses made from unpasteurised goat`s milk, such as Feta and Chevre, the literature data on their fatty acid composition are insufficient to assess the stage of ripening, milk fat quality, and regional authentication, which is an urgent task for assessing their dietary and nutritional characteristics.

The aim of the research was to conduct a detailed study of the dynamics of fatty acid content and lipid quality in artisanal cheeses that are in demand on the market, in particular, brine Feta cheese with a long ripening and storage period and soft Chevre cheese, which ripens with the participation of noble mould, made from unpasteurised goat's milk.

Experimental part

Materials. For studies of the fatty acid composition, brine Feta cheese and Chevre cheese with white noble mould were produced under the conditions of the Eco Farm "Zhuravka" (Kyiv region, Ukraine) during May 2022 – December 2024. 3 batches of Feta cheese, each weighing 5 kg, as well as 15 wheels of Chevre cheese weighing 180–200 g each, were used for the analysis (Table 1).

Table 1

Technological scheme of production of Feta and Chevre cheeses

Technological stage	Feta	Chevre
1	Unpasteurised goat`s milk	Unpasteurised goat`s milk
2	Heating to 33°C and adding mesophilic starter culture MA 11 (Danisco France SAS, France)	Heating milk to 32°C and adding mesophilic starter culture MA 11 (Danisco France SAS, France)
3	Adding liquid rennet enzyme Rennet Liquid 92/8 (Pamir Service, Kyiv, Ukraine)	Adding of AGE M-GC mould starter (*Geotrichum candidum)* and AGE M-PC (*Penicillium candidum)* (IGEA Cultures, Italy)
4	Coagulating milk and cutting the curd	Adding liquid rennet enzyme Rennet Liquid 92/8 (Pamir Service, Kyiv, Ukraine)
5	Transferring the curd into a mould and separating the whey	Milk coagulation and curd formation
6	Cutting cheese into portions and packing into containers	Whey separation
7	Salting of the cheese in a 9% brine solution prepared with whey and table salt	Salting of the curd with crystalline salt
8	Cheese storage in brine 30 months	Forming cheese wheels
9	-	Cheese wheels ripen on a drainage mat for 20 days
10	-	Packing cheese wheels in parchment paper
11	-	Cheese wheels ripen in packaging for 20 days

The cheeses were made from the milk of Anglo-Nubian goats that grazed during the growing season on natural pastures. The goats' diet contained a sufficient amount of roughage, succulent and concentrated feed and was balanced in terms of nutrients and biologically active substances.

After production, all cheeses were placed in a ripening chamber. Samples of Feta cheese were taken on the 7th day, 18th and 30th month of ripening, 5 samples weighing 200–250 g from each batch. Samples of Chevre cheese in the amount of 5 wheels were taken for research on the 3rd, 20th and 40th day of ripening.

The study of the fatty acid composition of cheeses was conducted at the Ukrainian Laboratory of Quality and Safety of Agro-Industrial Complex, which is accredited according to the quality system DSTU EN ISO/IEC 17025:2019 and is a structural unit of the National University of Life and Environmental Sciences of Ukraine. Fat was extracted from cheese samples [19]. After that, hydrolysis and methylation of fatty acids were performed [20]. Chromatographic analysis of fatty acids was performed on a Trace Ultra gas chromatograph (USA), using flame-ionisation detector (FID) using a high-polar capillary column SPTM -2560 (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 conditions: column temperature 140–240 °C, detector temperature 260 °C. A TriPlus autosampler (USA) was used to introduce samples. The analysis duration was 65 min. Qualitative and quantitative identification of fatty acid peaks was performed using an analytical standard Supelco 37 Component FAME Mix (made in the USA). The calculation was carried out using the internal normalisation method in %. Each sample was analysed in 3 replicates.

The following fatty acids were determined in cheeses: butyric (4 : 0), caproic (6 : 0), caprylic

(8 : 0), capric (10 : 0), undecanoic (11 : 0), lauric (12:0), myristic (14:0), myristoleic (14 : 1), pentadecanoic (15 : 0), palmitic (16 : 0), stearic (18 : 0), oleic (18 : 1ω9), linoleic (18 : 2ω6), linolenic (18 : 3ω3), arachidic (20 : 0).

Calculated indices were used to determine the quality of milk fat in soft cheeses.

1. Δ^9 desaturase Index (C_{14}) was determined by formula 1 [21].

Δ^9 desaturase Index (C_{14}) = C14:1/(C14:1 + C14:0) (1).

2. Δ^9 desaturase Index (C_{18}) was determined by the formula 2.

Δ^9 desaturase Index (C_{18}) = C18:1/(C18:1 + C18:0) (2).

This index shows the intensity of dehydration of myristic acid with its subsequent conversion to myristoleic acid in milk fat during the ripening of soft cheeses.

3. The index of atherogenicity (IA) was determined by formula 3 [22; 23]

IA = [C12:0 + (4 x C14:0) + C16:0]/(MUFA + PUFA) (3).

This index shows the ratio of the sum of the main saturated (proatherogenic) to the main unsaturated (antiatherogenic) fatty acids of milk fat. To calculate the sum of the main saturated fatty acids, lauric, myristic, and palmitic acids were used, and to calculate the sum of unsaturated fatty acids, monounsaturated and polyunsaturated fatty acids were used. Depending on their atherogenicity, coefficients were assigned, in particular, myristic acid - 4.

4. Content of hypocholesterolemic fatty acids (DFA) was calculated using formula 4 [24].

DFA = MUFA + PUFA + C18:0 (4).

5. Hypercholesterolemic fatty acid (OFA) content was calculated using formula 5 [24].

OFA = C12:0 + C14:0 + C16:0 (5).

6. Hypocholesterolaemic/hypercholesterolaemic ratio (H/H) was calculated using formula 6. [25].

H/H = (C18:1*n*−9 + C18:2 ω6 + C18:3 ω3)/(C12:0 + C14:0 + C16:0) (6).

7. The index of thrombogenicity (IT) of milk fat of soft cheeses was calculated as the ratio of the sum of saturated fatty acids: myristic, palmitic and stearic (prothrombogenic) to unsaturated (antithrombogenic) according to formula 7 [22]. Monounsaturated and polyunsaturated fatty acids ω6 were assigned a coefficient of 0.5 for significantly lower atherogenicity, and polyunsaturated fatty acids ω3 were assigned a coefficient of 3. IT shows the vascular thrombogenicity of fat.

IT = C14 + C16 + C18/[(0.5MUFA + 0.5PUFA ω6 + 3PUFAω3) + PUFA ω3/PUFA ω6] (7).

8. To determine the actual nutritional value and dietary characteristics of fatty acids, their weighted coefficients were taken into account in calculating the healthy fatty index (HFI) according to formula 8 [26].

HFI = (MUFA·2+(ω6·4)+(ω3·8)+(ω3/ω6)]/[(SFA·1)+(MUFA·0.5)+(ω6·0.25)+(ω3·0.125)+(ω6/ω3)] (8)

Statistical processing. Statistical processing of the research results was carried out using one-way analysis of variance (ANOVA). Digital material was processed using correlation and regression analyses, data in the tables are presented as x ± SD (mean ± standard deviation). For this purpose, Microsoft Excel 2021 software was used, as well as XLSTAT. The difference between the fatty acid composition indicators was determined within the ripening range of each soft cheese name. The probability of the difference was assessed using the Tukey test at $P < 0.05$ (taking into account the Bonferroni correction).

Results and Discussion

During the ripening period of brine Feta cheese, an increase in the proportion of saturated fatty acids in the lipid structure was found, in particular, at 18 months by 0.73 % and at 30 months of ripening – by 7.18 % compared to the initial content. This occurred due to an increase in the concentration of short-chain (butyric, caproic, caprylic), medium-chain (capric, lauric) and long-chain – arachidic acids in the fat of this cheese (Tables 2, 3).

Table 2

Fatty acid content in Feta cheese depending on ripening period (% of the total fatty acid content), x ± SD, n = 5

Acid	Cheese ripening period		
	7 days	18 months	30 months
Butyric acid, C 4:0	2.22 ± 0.04^a	2.86 ± 0.19^b	3.36 ± 0.11^c
Caproic acid, C 6:0	2.78 ± 0.10^a	3.53 ± 0.09^b	3.70 ± 0.14^b
Caprylic acid, C 8:0	2.81 ± 0.11^a	3.28 ± 0.08^b	4.21 ± 0.07^c
Capric acid, C 10:0	10.24 ± 0.12^a	10.03 ± 0.14^a	12.69 ± 0.18^b
Undecanoic acid, C 11:0	0.41 ± 0.02^a	0.37 ± 0.03^b	0.25 ± 0.01^c
Lauric acid, C 12:0	2.83 ± 0.07^a	3.78 ± 0.12^b	5.00 ± 0.12^c
Myristic acid, C 14:0	10.14 ± 0.37^a	9.73 ± 0.21^{ab}	9.23 ± 0.16^b

Continued from Table 2

Myristoleic acid, C 14:1	0.64 ± 0.04[a]	0.87 ± 0.04[b]	0.43 ± 0.02[c]
Pentadecanoic acid, C 15:0	0.68 ± 0.03[a]	0.54 ± 0.03[b]	0.82 ± 0.03[c]
Palmitic acid, C 16:0	23.47 ± 0.28[a]	21.14 ± 0.06[b]	23.69 ± 0.15[a]
Stearic acid, C 18:0	12.47 ± 0.31[a]	13.45 ± 0.20[b]	11.74 ± 0.11[c]
Oleic acid, C 18:1n9c	26.63 ± 0.29[a]	24.88 ± 0.22[b]	19.85 ± 0.29[c]
Linoleic acid, C 18:2n6c	3.68 ± 0.13[a]	4.28 ± 0.14[b]	3.55 ± 0.09[a]
Alpha-linolenic acid, C 20:0	0.34 ± 0.03[a]	0.40 ± 0.02[a]	0.88 ± 0.04[b]
Arachidic acid, C 18:3n3	0.68 ± 0.06[a]	0.86 ± 0.03[b]	0.62 ± 0.03[c]

Note: superscript letters [a,b,c] indicate a significant difference between values in the same row of the table (P < 0.05)

At the same time, the content of butyric, caprylic and lauric acids was characterised by a strong positive correlation on the ripening period of Feta cheese: the correlation coefficients were respectively (r = 0.973 ± 0.043, P < 0.001), (r = 0.959 ± 0.053, P<0.001), (r = 0.983 ± 0.035, P < 0.001), which was consistent with the regression line (Fig. 1).

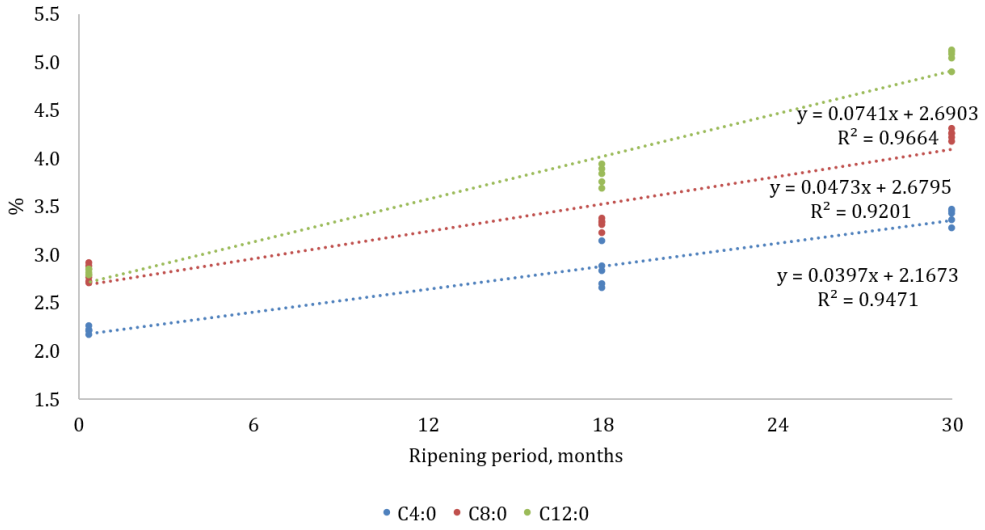

Fig. 1. Dependence of the content of individual saturated fatty acids in Feta cheese on the ripening period, n = 15

The main saturated fatty acids of Feta cheese were palmitic, stearic, capric, and myristic, although no characteristic dependence of the dynamics of their content on the ripening period was found.

In accordance with the increase in the proportion of saturated fatty acids, the proportion of unsaturated fatty acids decreased during the ripening process of Feta cheese. This was mainly due to monounsaturated fatty acids, the basis of which was oleic. The strong positive correlation of its content in fat on the ripening period of cheese was confirmed by the correlation: r = -0.920 ± 0.074, P < 0.001.

Two polyunsaturated acids were found in Feta cheese – linoleic and linolenic, which formed the basis of ω6 PUFA and ω3 PUFA, respectively. The dynamics of their content in the fat of this cheese was similar, both acids reached peak concentration at 18 months, and ω3/ω6 PUFA was maximum at 7 days and 30 months of ripening (Tables 2, 3).

Table 3

Lipid quality of Feta cheese depending on the ripening period (% of the total fatty acid content), x ± SD, n = 5

Indicator	Cheese ripening period		
	7 days	18 months	30 months
Σ SFA	68.38 ± 0.28[a]	69.11 ± 0.35[b]	75.56 ± 0.24[c]
Σ UFA	31.63 ± 0.27[a]	30.89 ± 0.36[b]	24.44 ± 0.25[c]
Σ MUFA	27.27 ± 0.26[a]	25.75 ± 0.22[b]	20.26 ± 0.29[c]
Σ PUFA	4.36 ± 0.14[a]	5.14 ± 0.13[b]	4.17 ± 0.08[a]
Σ ω3 PUFA	0.68 ± 0.06[a]	0.86 ± 0.03[b]	0.62 ± 0.03[a]
Σ ω6 PUFA	3.67 ± 0.13[a]	4.28 ± 0.14[b]	3.55 ± 0.09[a]
ω3/ω6 PUFA	5.43 ± 0.51[ab]	4.96 ± 0.23[b]	5.74 ± 0.39[a]
Σ SCFA (4-8)	7.81 ± 0.14[a]	9.67 ± 0.31[b]	11.27 ± 0.17[c]

Continued from Table 3

Σ MCFA (10-16)	48.41 ± 0.35[a]	46.45 ± 0.23[b]	52.10 ± 0.30[c]
Σ LCFA (17-20)	43.79 ± 0.32[a]	43.88 ± 0.41[a]	36.64 ± 0.21[b]
DFA	44.09 ± 0.31[a]	44.34 ± 0.39[a]	36.18 ± 0.23[b]
OFA	36.44 ± 0.33[a]	34.65 ± 0.16[b]	37.92 ± 0.17[c]
Δ^9 desaturase Index (C_{14})	0.059 ± 0.003[a]	0.082 ± 0.004[b]	0.044 ± 0.001[c]
Δ^9 desaturase Index (C_{18})	0.681 ± 0.007[a]	0.649 ± 0.004[b]	0.628 ± 0.005[c]
AI	2.11 ± 0.06[a]	2.07 ± 0.03[a]	2.68 ± 0.05[b]
H/H	0.85 ± 0.01[a]	0.87 ± 0.02[b]	0.63 ± 0.01[b]
IT	2.60 ± 0.05[a]	2.49 ± 0.04[b]	3.20 ± 0.04[c]
HFI	0.85 ± 0.02[a]	0.86 ± 0.01[a]	0.65 ± 0.01[b]

Note: superscript letters [a,b,c] indicate a significant 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

The proportion of DFA in Feta cheese practically did not change from 7 days to 18 months but decreased by 7.91 % at 30 months of ripening, which is consistent with the decrease Δ^9 desaturase Index (C_{14}) i Δ^9 desaturase Index (C_{18}). The OFA content, index of thrombogenicity and index of atherogenicity in the fat of Feta cheese reached their maximum value at the end of the ripening period – at 30 months. According to the fat quality indicators, in particular the H/H and HFI indices, Feta cheese was characterised by the highest dietary properties in the period from the 7 days to 18 months of ripening (Table 3). It should be noted that for this cheese, the latter two indices showed virtually no difference, indicating that they could be considered interchangeable.

Analysis of the fatty acid composition of Chevre cheese, which is characterised by a short ripening period involving white noble mould, showed that its main saturated fatty acids were palmitic, stearic, myristic, and capric, and the basis of unsaturated fatty acids was oleic (Table 4).

Table 4

Fatty acid content in Chevre cheese depending on the ripening period (% of the total fatty acid content), x ± SD, n = 5

Acid	Cheese ripening period		
	3	20	40
Butyric acid, C 4:0	2.50 ± 0.10[a]	2.85 ± 0.08[b]	2.56 ± 0.11[a]
Caproic acid, C 6:0	2.59 ± 0.11[a]	2.97 ± 0.07[b]	2.88 ± 0.04[b]
Caprylic acid, C 8:0	2.64 ± 0.12[a]	2.75 ± 0.11[a]	3.60 ± 0.15[b]
Capric acid, C 10:0	8.81 ± 0.19[a]	8.83 ± 0.24[a]	9.55 ± 0.23[b]
Undecanoic acid, C 11:0	0.51 ± 0.03[a]	0.85 ± 0.04[b]	0.53 ± 0.03[a]
Lauric acid, C 12:0	4.39 ± 0.27[a]	3.66 ± 0.11[b]	3.69 ± 0.12[b]
Myristic acid, C 14:0	7.66 ± 0.33[a]	6.85 ± 0.24[b]	7.52 ± 0.31[a]
Myristoleic acid, C 14:1	1.13 ± 0.04[a]	1.14 ± 0.03[a]	0.47 ± 0.04[b]
Pentadecanoic acid, C 15:0	0.53 ± 0.02[a]	0.40 ± 0.03[b]	0.61 ± 0.12[a]
Palmitic acid, C 16:0	21.79 ± 0.27[a]	21.60 ± 0.15[a]	20.33 ± 0.23[b]
Stearic acid, C 18:0	12.40 ± 0.09[a]	12.31 ± 0.39[a]	13.28 ± 0.45[b]
Oleic acid, C 18:1n9c	30.90 ± 1.17[a]	31.50 ± 0.35[a]	28.46 ± 0.24[b]
Linoleic acid, C 18:2n6c	3.40± 0.14[a]	4.13 ± 0.36[b]	4.61 ± 0.13[c]
Alpha-linolenic acid, C 20:0	0.60 ± 0.03[a]	0.13 ± 0.01[b]	0.91 ± 0.07[c]
Arachidic acid, C 18:3n3	0.16 ± 0.02[a]	0.10 ± 0.01[a]	1.04 ± 0.08[b]

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

The ratio of saturated and unsaturated fatty acids changed little from the 3rd to the 20th day of its ripening. On the 40th day, there was a decrease in the content of saturated fatty acids in this cheese in favour of unsaturated fatty acids (Table 5). Such an increase in the proportion of saturated acids in Chevre cheese was provided mainly by short-chain acids, in particular caproic and caprylic, medium-chain - capric and long-chain - stearic, against the background of a decrease in the proportions of medium- and long-chain monounsaturated acids such as myristoleic and oleic (Tables 4, 5). This is consistent with the values of Δ^9 desaturase Index (C_{14}) and Δ^9 desaturase Index (C_{18}), which on the 40th day of cheese ripening decreased by 0.71 and 0.32, respectively, compared to the initial value.

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Table 5

Lipid quality of Chevre cheese depending on the ripening period (% of the total fatty acid content), x ± SD, n = 5

Indicator	Cheese ripening period, day		
	3	20	40
Σ SFA	64.41 ± 1.08^{ab}	63.14 ± 0.52^{a}	65.43 ± 0.31^{b}
Σ UFA	35.59 ± 1.07^{ab}	36.86 ± 0.54^{a}	34.57 ± 0.30^{b}
Σ MUFA	32.03 ± 1.15^{a}	32.63 ± 0.34^{a}	28.92 ± 0.23^{c}
Σ PUFA	3.55 ± 0.14^{a}	4.23 ± 0.36^{b}	5.65 ± 0.13^{c}
Σ ω3 PUFA	0.16 ± 0.02^{a}	0.10 ± 0.01^{a}	1.04 ± 0.08^{b}
Σ ω6 PUFA	3.40 ± 0.15^{a}	4.13 ± 0.36^{b}	4.61 ± 0.13^{c}
ω3/ω6 PUFA	21.80 ± 2.06^{a}	43.16 ± 5.86^{b}	4.47 ± 0.35^{c}
Σ SCFA (4-8)	7.73 ± 0.24^{a}	8.52 ± 0.11^{b}	9.04 ± 0.18^{c}
Σ MCFA (10-16)	44.82 ± 0.84^{a}	43.32 ± 0.34^{b}	42.69 ± 0.47^{b}
Σ LCFA (17-20)	47.45 ± 1.07^{a}	48.16 ± 0.32^{a}	48.28 ± 0.56^{a}
DFA	47.98 ± 1.04^{a}	49.17 ± 0.35^{a}	47.85 ± 0.57^{a}
OFA	33.84 ± 0.84^{a}	32.11 ± 0.17^{b}	31.54 ± 0.48^{b}
Δ^9 desaturase Index (C_{14})	0.129 ± 0.004^{a}	0.143 ± 0.008^{a}	0.058 ± 0.002^{b}
Δ^9 desaturase Index (C_{18})	0.714 ± 0.009^{a}	0.719 ± 0.008^{a}	0.682 ± 0.007^{c}
AI	1.60 ± 0.10^{a}	1.43 ± 0.04^{b}	1.56 ± 0.05^{a}
H/H	1.02 ± 0.06^{a}	1.11 ± 0.02^{a}	0.08 ± 0.03^{a}
IT	2.30 ± 0.10^{a}	2.18 ± 0.05^{b}	2.05 ± 0.03^{c}
HFI	0.77 ± 0.03^{a}	0.67 ± 0.02^{b}	0.99 ± 0.01^{c}

Note: See table 3

Despite the decrease in the total proportion of unsaturated acids in the fat structure of Chevre cheese, the proportion of polyunsaturated fatty acids increased both due to Σ ω3 PUFA and Σ ω6 PUFA. This corresponded to an increase in the levels of linolenic acid by 0.88-0.94% and linoleic acid by 0.73–1.21% on 40th day of ripening compared to the 3rd and 20th days. A strong positive correlation of the content of linoleic acid on the ripening period of Chevre cheese was found, which was characterised by a correlation at the level of $r = 0.921 \pm 0.073$, $P < 0.001$.

It is especially necessary to note the significant fluctuation of ω3/ ω6 PUFA during the ripening period of Chevre cheese: starting from the 3rd day to the 20th, it increased by 2 times, and on the 40th day, it decreased by 4.9 times compared to the initial value (Table 5).

Another important indicator of the quality of Chevre cheese fat is the DFA content and the H/H index, which were not affected by the ripening period. The OFA share decreased by 1.73–2.30 % with increasing ripening period of Chevre cheese, which, together with a decrease in IT by 0.12–0.25 and an increase in HFI by 0.22, allowed the 40-day ripened Chèvre to be considered the most dietetically favourable product.

Summarising the obtained research results, it can be noted that 15 fatty acids were found in goat cheeses Feta and Chevre, of which 11 are saturated and 4 are unsaturated. In contrast, the number of fatty acids in cheeses made from cow's milk Caciocavallo Silano (PDO) reached 35, of which 14 were saturated, 9 were monounsaturated, and 12 were polyunsaturated fatty acids [27]. In another study, 27 fatty acids have been identified in Coalho cheese from unpasteurised cow's milk, of which 15 are saturated, 7 are monounsaturated, and 5 are polyunsaturated [28].

Despite the common origin of the raw milk, the fatty acid content of goat Feta cheeses and Chevre differed significantly. Brine Feta cheese was superior to Chevre cheese in terms of saturated fatty acid content but inferior in unsaturated fatty acid content at all ripening periods. According to literature data, the proportion of SFA in goat cheeses ranged from 58 to 74 % [27], which is consistent with the data obtained in this study.

A distinctive feature of the ripening of brine Feta cheese made from sheep's milk was an increase in the content of saturated fatty acids in the periods after the 37th and 48th days of ripening against the background of a decrease in the proportion of monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) [29], which was consistent with the data on the dynamics of the fatty acid composition of goat Feta cheese, with the exception of PUFA.

The proportion of SCFA in goat cheeses reached an average of 11.2–37.0 %, while in Feta and Chevre cheeses, significantly lower values were obtained, which may be due to feeding conditions [30], grazing and botanical composition of the herbage [31], climatic [32], seasonal [33], physiological factors [34] and breed

characteristics of ruminants [35]. The saturated fatty acids of the cheese were mainly palmitic and stearic acids, while the content of lauric and myristic acids increased with ripening time up to 120 days [36], which is not inconsistent with the data obtained in this study. Content of monounsaturated fatty acids during the ripening period of Caciocavallo Silano cheese (PDO) decreased slightly due to the oleic acid content from 22.6 % to 21.3 %, while in Chevre and Feta cheeses, there was also a simultaneous decrease in the proportion of myristoleic acid. The content of polyunsaturated fatty acids, in particular linoleic and α-linolenic, during the ripening of Caciocavallo Silano cheese (PDO) increased, which was more consistent with the characteristics of Chevre cheese, but not Feta. In terms of MUFA content, Feta and Chevre cheeses had characteristics that were in the range of 19.7–31.4 %, PUFA ω3 – 0.3–1.3 %, ω6 – 1.4–7.0 % and were consistent with similar studies by other scientists [37].

Among the polyunsaturated fatty acids that are of interest in terms of their positive impact on human health, conjugated linoleic acid occupies an important place. Its content in Greek cheeses, including Feta cheese, are quite variable, and in the process of ripening reached 0.75 % with the following decrease during the period of storage to 0.52 % [29], but this pattern was not characteristic of goat Feta cheese, while in Chevre cheese its content increased during the ripening process. The latter may be associated with the activity of bacteria and fungi that form the basis of white noble mould. The obtained data are confirmed in the literature, where the influence of the technological process, starter cultures (bacteria, moulds) and the ripening period of cheese on the profile and content of fatty acids has been repeatedly emphasised [38]. It is believed that lactic acid bacteria of the genera *Lactobacillus, Lactococcus, Bifidobacterium* and *Propionibacterium* [39] are able to produce linoleic acid during cheese ripening. The most active lactic acid bacteria species in this regard were *Lactiplantibacillus plantarum, Lactobacillus acidophilus, Lacticasebacillus casei, and Bifidobacterium lactis* [40]. Most of these bacteria belong to the autochthonous microbiota of goat cheeses made from unpasteurised milk [41; 42].

Polyunsaturated fatty acids of cheeses made from cow's, sheep's or goat's milk are particularly valued for the ratio of ω6 to ω3 polyunsaturated fatty acids, which in most cases was in the range of 1:1–1:4. [43; 44]. Conducted analysis of goat cheeses [27] showed that ω3/ ω6 PUFA can vary within the range of 1.14–7.43, DFA – 31.30–44.55, OFA – 42.51–53.73, AI –1.12–2.14, TI – 1.58–3.13, and H/H – 0.44–0.75. In another study, in Greek Tsalafouti cheeses made from small ruminant milk, ω3/ω6 PUFA indices varied within the range of 2.47–4.31, IA – 1.65–2.99, IT – 1.99–3.06, and H/H – 0.513–0.923. According to the World Health Organization standard, ω3/ω6 PUFA in the diet should be within 5:1–10:1, which meets the criterion of optimal support of human health.

As for the indices of atherogenicity and thrombogenicity, there is no standard for them, but the lower their value, the lower the risk of platelet aggregation and, accordingly, the development of ischemic heart disease. The H/H index demonstrates the functional activity of fatty acids in lipoprotein metabolism and their ability to transport cholesterol, which in turn reflects the state of the cardiovascular system. Accordingly, the higher this ratio in cheese, the more beneficial it is for human health [45]. In this study, the coefficients obtained, which characterise the quality of milk fat of Feta cheese, prevailed over the average values of the above goat cheeses for the OFA index and, in certain periods of ripening, the H/H index, and for Chevre cheese - for the DFA, OFA and H/H indices. Such results are probably related not only to the ripening period, the presence of sources of fatty acids in the goat diet, but also to the use of raw milk for cheese production [46].

This point of view was confirmed by studies of cheeses made from raw cow's milk, in particular "Călimani" Schweizer, "Călimani" Caşcaval, "Călimani" smoked Caşcaval and "Călimani" Telemea brine. In such cheeses, an increase in the content of polyunsaturated fatty acids by 5.6-13.7 %, an increase in the polyunsaturation index by 4.3–7.8 % and the H/H ratio by 1.8–3.7 % were found against the background of a decrease in AI and IT by 1.9–4.3 %. This is also due to the presence of bacteria of the *Enterobacteriaceae* family, which are present in cheeses made from unpasteurised milk [47], while pasteurisation changes the microbiome of cheeses not always for the better, which worsens its sensory characteristics [48].

Thus, to develop a comprehensive criterion for assessing the quality, safety, age and authenticity of artisanal soft cheeses made from unpasteurised goat`s milk, the fatty acid profile and milk fat quality indices can be used simultaneously with other microbiological, physicochemical, and organoleptic indicators.

Conclusion

The necessity of using the fatty acid composition and milk fat quality indicators of artisanal soft Feta and Chevre cheeses made from unpasteurized goat`s milk as a component of the criteria for determining their nutritional and biological value, age, and authenticity has been proven.

In brine Feta cheese and Chevre cheese, which is ripened with the help of white noble mould, 15 fatty acids were detected at all stages of ripening, of which 11 were saturated and 4 were unsaturated. The main saturated fatty acids in both cheeses were palmitic, stearic, capric, and myristic.

As the ripening period of feta cheese increased, the proportion of saturated fatty acids increased, mainly due to butyric, caproic, caprylic, capric, lauric and arachidic acids. The proportion of unsaturated fatty acids inversely depended on the ripening time of Feta cheese, which is associated with a decrease in the level of oleic acid (r = –0.920 ± 0.074, P <0.001). The basis of polyunsaturated fatty acids in Feta and Chevre cheeses was linoleic and linolenic, which belong to ω6 PUFA and ω3 PUFA. The proportion of DFA in Feta cheese decreased by 7.91 %, and the OFA content, index of thrombogenicity and index of atherogenicity reached their maximum value at 30 months of ripening. According to the H/H and HFI indices, Feta cheese acquired the best dietary characteristics from the 7th day to the 18th month of ripening. The indicators of the fatty acid composition and lipid quality of Feta cheese indicate its suitability for storage up to the 30th month in brine and hermetically sealed packaging in a refrigerated state.

During the ripening of Chevre cheese, an increase in the content of polyunsaturated fatty acids was found due to Σω3 PUFA and Σω6 PUFA. The content of linoleic acid was characterised by a strong positive correlation on the ripening period of Chevre cheese (r = 0.921 ± 0.073, P <0.001). A distinctive feature of the ripening of Chevre cheese was a significant fluctuation of ω3/ ω6 PUFA: 1:4.47–1:43.16, which reached the optimal value for the human diet on the 40th day. According to the fat quality indicators: DFA, OFA content, as well as the H/H, IT and HFI indices, it can be assumed that Chevre cheese acquires the most dietary properties on the 40th day of ripening.

In the future, to develop a comprehensive criteria for assessing the authenticity of artisanal soft goat cheeses Feta and Chevre made from unpasteurised milk, it is necessary to study the microbiome and microstructural changes in their texture depending on the ripening period.

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