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Study of Fatty-acid Composition of Goat and Sheep Milk and Its Transformation in the Production of Yogurt

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Abstract

The information on the structure of fatty acids is crucial for the production and promotion of goat and sheep milk in the manufacture of dairy products. The fatty-acid profile of milk fat can affect the nutritional value and market value of dairy products. The purpose of the research is to study the properties of fatty-acid composition of goat and sheep milk and its transformation in the process of yogurt production. The study of fatty-acid composition was performed using the method of gas chromatography. The milk of goats of Zaanen breed and sheep of North Caucasian breed, as well as yogurt produced from a mixture of goat and sheep milk in a ratio of 1:1 have become the objects of the study. It was found that goat's milk contains 12% less saturated fatty acids than sheep's milk. Oleic, stearic and palmitic acids are the main fatty acids found in the fat phase of milk and yogurt production. Changes in the concentration of individual fatty acids during milk processing and in the period of yogurt storage were noted. As a result of maturation and seven-day storage, the amount of saturated fatty acids in yogurt increased by 5% compared to the original milk mixture. The content of polyunsaturated fatty acids in yogurt decreased by 19.27 %. The highest ratio value of hypocholesterolemic and hypercholesterolemic fatty acids was noted in goat milk. It is proved that goat milk is characterized by the most acceptable fatty acid composition in terms of healthy nutrition and prevention of atherosclerosis and thrombosis. A tendency to reduce the amount of monounsaturated and polyunsaturated fatty acids, with a simultaneous increase in the content of saturated fatty acids is noted in the process of yogurt production and storage. It was found that the production of yogurt with the use of goat's milk in the mixture allows reducing the values of atherogenicity and thrombogenicity indices. The results of the study provide an information basis for the production of qualitatively new fermented milk drinks with a fatty-acid profile favorable for human health.

Keywords: milk, yogurt, sheep, goat, transformation, lipids, fatty-acid profile, dairy products, rheological properties

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1. Introduction

Milk has a high nutritional and biological value and is a significant part of the human diet [1, 2]. However, the milk of different species of animals has some differences in the physicochemical and biochemical composition. The features of the composition of milk of different animals entail a change in technological processes in their industrial processing. In addition, it is necessary to point out the differences in the biological potential of milk of different species of animals. Even though dairy cows produce the largest share of the world's milk supply, goat milk is drunk by a significant number of people around the world. Goat's milk and its products are important daily food sources of proteins, phosphates and calcium for people from developing countries. Dairy goat farming is a vital sector of agriculture in developed countries, especially in the Mediterranean region such as France, Italy, Spain and Greece. This indicates that raising dairy goats and sheep is not necessarily synonymous with poverty or an underdeveloped business sector.

Insufficient or unbalanced nutrition leads to disorders of body functions. The imbalance of lipid intake in the human body leads to hypertension and obesity, which in turn is a risk factor for arthrosis, cardiovascular diseases [3, 4]. Goat's and sheep's milk, unlike cow's milk, contains more short-and medium-chain fatty acids (medium-chain triglycerides), which have a unique metabolic ability to provide energy to growing children and be used to treat patients with malabsorption. Information on the structure of fatty acids is crucial for the production and promotion of goat and sheep milk in the manufacture of dairy products. The fatty-acid profile of milk fat can affect the nutritional and market value of dairy products. Lipids are considered to be extremely important biologically active components of sheep's milk because of their high nutritional value and influence on the physicochemical, sensory and production properties of dairy products.

Sheep milk is of interest as a food source containing significant amounts of ω-3 and ω-6 fatty acids in milk fat, as well as other less common ones such as linoleic acid isomers [1]. Sheep's milk is widely produced in semi-arid countries and is mainly used for milk consumption and the production of a wide range of cheeses, fermented milk products (e.g. liquid, viscous, concentrated and dry) and, to a lesser extent, milk powder. Sheep's milk is characterized by a high content of dry substances and a large amount of minerals and vitamins. The micellar structures of sheep's and goat's milk differ from cows in diameter, hydration and mineralization. Goat milk casein micelles contain more calcium and inorganic phosphorus, are less solvated and less resistant to heat, they lose casein more easily than cow casein micelles [5--7]. Lipids in goat and sheep milk are represented by fat globules of smaller size, which contributes to better digestibility [6--9]. Intensive research on sheep and goat milk has shown that lipid components can have many benefits [10-16]. The studies have focused on trans-acid and conjugated isomers of linoleic acid, as the latter are thought to have beneficial effects on human health, whereas the former appear to have certain negative effects. The increase in the production of fermented milk drinks from goat and sheep milk is due to their high nutritional value and digestibility.

The difference in the composition of goat and sheep milk, preliminary preparation of milk raw materials, makes it possible to produce yogurts with different rheological properties: viscous, low-viscous (drinking).

In the production of yogurt from goat's and sheep's milk, it is necessary to use technological methods taking into account the milk composition peculiarities. Starter cultures used in the production of yogurt contribute to the preliminary hydrolysis of proteins [2]. The most commonly used microorganisms, the optimal growth temperature of which is within 37-45°C are Streptococcus thermophilus, Lactobacillus delbrueckii subsp. bulgaricus and subsp. lactis, probiotic lactobacilli (Lactobacillus acidophilus, helveticus, rhamnosus, casei subsp. casei, paracasei and plantarum) and Bifidobacterium (Bifidobacterium adolescentis, breve, bifidum, infantis, animalis subsp. lactis, subsp. longum and animalis). Differences in the composition of protein fractions of sheep milk are the main factor influencing the duration of coagulation and rheological properties of the formed clot in the production of fermented milk drinks [9]. Yogurt made from goat's milk is characterized by a loose clot, unlike yogurt made from sheep's milk.

A wide range of dairy products with specified rheological characteristics and high biological value can be obtained using a mixture of goat and sheep milk. Since goat's milk also contains more non-protein nitrogenous substances and contains fewer casein varieties than sheep's and cow's milk [6], this results in a looser structure of goat's milk yogurt, unlike sheep's milk, which has good coagulation capacity. However, it must be remembered that the product produced from a mixture of goat's and sheep's milk must be labeled accordingly. The absence of the information about the milk mixture composition on the yogurt packaging can be regarded as a falsification of the product.

2. Methods and Equipment

2.1. Methods

2.1.1. Diagrammatic representation

The milk of goats of Zaanen breed and sheep of North Caucasian breed, as well as yogurt obtained from a mixture of goat and sheep milk have become the objects of the study. The yogurt was made from a mixture of goat's and sheep's milk in a ratio of 1:1, pasteurized at 63 C for 30 minutes before manufacture, using Streptococcus ssp. thermophilus and Lactobacillus delbrueckii ssp. Bulgaricus. The study of fatty acid composition was performed using the method of gas chromatography in accordance with the State Industry Standard of the Russian Federation GOST 32915-2014 "Milk and Dairy Products. Determination of Fatty Acid Composition of the Fatty Phase Using Gas Chromatography".

The atherogenicity index and thrombogenic index were calculated to assess the lipid quality of the fat phase of the raw milk and the finished product. Atherogenicity index (AI) and thrombogenic index (TI) were calculated by the formulas [16]:

$$AI = \frac{[12:0(4 \cdot 14:0) + 16:0]}{\omega{-}3\ PUFA + \omega{-}6\ PUFA + MUFA} \tag{1}$$

$$TI = \frac{(14:0 + 16:0 + 18:0)}{0,5 \cdot MUFA + 0,5 \cdot \omega{-}6\ PUFA + 3 \cdot \omega{-}3\ PUFA} + \frac{\omega{-}3\ PUFA}{\omega{-}6\ PUFA} \tag{2}$$

where PUFA stands for polyunsaturated fatty acids, MUFA stands for monounsaturated fatty acids.

The correlation (C) between hypocholesterolemic (h) and hypercholesterolemic and (H) fatty acids was calculated according to equation [17]:

$$h/H = \frac{C18:1 + PUFA}{C14:0 + C16:0} \tag{3}$$

3. Results

In order to determine the potential of goat and sheep milk as raw materials for the production of healthy food products, an attempt is made to identify the specific features of the fatty-acid composition of the milk raw materials under study and its transformation in the production of yogurt. The fatty-acid composition of milk of goats of Zaanen breed and sheep of North-Caucasian breed is investigated. The studies revealed the presence of 42 fatty acids.

Essential fatty acids (which are 14 in number) and minor fatty acids are distinguished depending on the relative content of fatty acids in milk fat. The content of each of the essential fatty acid exceeds 1%, minor fatty acid content is less than 1%. Essential fatty acids alone can produce about 1.5 thousand of mixed triacylglycerols when participating in the formation of triacylglycerols. This digital example gives an idea of the complexity of milk fat and the variety of factors that determine its composition, and, consequently, physical and chemical properties. Quantitative determination of the content of fatty acids in milk fat was carried out using the methods of gas-liquid chromatography.

The share of the essential fatty acids in milk fat accounts for 98-99%, so it is this group of acids that mainly determines the properties of milk fat.

Figure 1 shows a profile consisting of fourteen fatty acids, the concentration of which exceeds 1% in the fat phase of milk. The sum of fourteen essential fatty acids accounts for 98.5 %. The sum of the remaining twenty-eight fatty acids which, including fatty acids in the forms of cis- and trans- isomers defined in the fat phase profile, together make up about 1.5 %. (1,611). The values given in Figure 1 below represent the percentage of all fatty acids analyzed, but not the total amount of fat in goat's and sheep's milk.

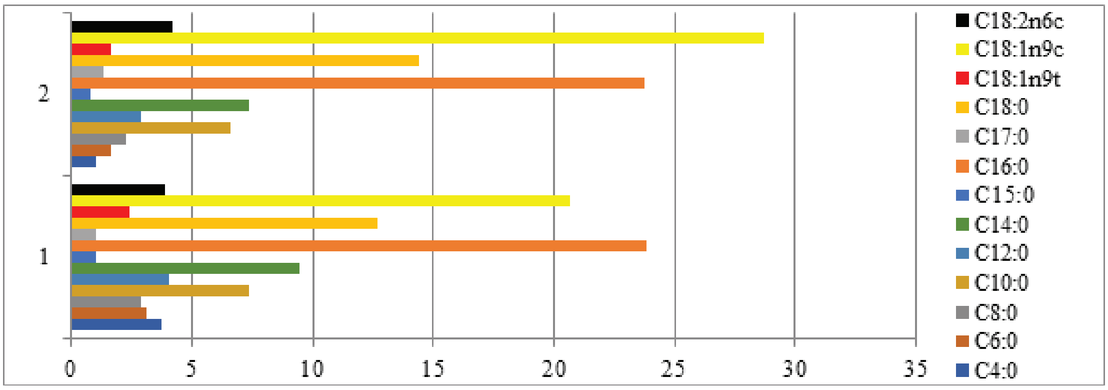

Figure 1: Fatty-acid profile of: 1 -- sheep's milk; 2 -- goat's milk The content of cis-isomer of oleic acid (C18:1n9c) in goat's milk accounts for 28.7% of the total amount of fatty acids, which is 39% more than in sheep's milk. The concentration of saturated fatty acids in sheep's milk is 70 %, in goat's milk - 62% of the total sum of fatty acids. Sheep's milk has a much higher content of oil acid (C4:0), nylon acid (C6:0), caprylic acid (C8:0), caprine acid (C10:0), lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18: 0) than goat's milk.

The change of fatty-acid profile of a mixture of goat and sheep milk and ready yogurt produced on their basis in the process of seven-day storage is investigated. For the production of yogurt, a mixture of goat's milk and sheep's milk in a ratio of 1:1 was used. The fatty-acid profile of the goat's and sheep's milk mixture and the yogurt produced on their basis, which was stored for 7 days at a temperature of 4±2°C is shown in Figure 2.

Among unsaturated fatty acids, oleic acid (18: 1n-9) and linoleic acid (18: 2n-6) play an important role in protecting the human body from cardiovascular diseases. In total, the content of the three unsaturated fatty acids C18:1n9t, C18:1n9c, C18:2n6c in yogurt decreased by 4.8%. There was a significant decrease in the content of the cis-isomer of oleic fatty acid from 23% to 18.7% during fermentation and storage of yogurt. A similar

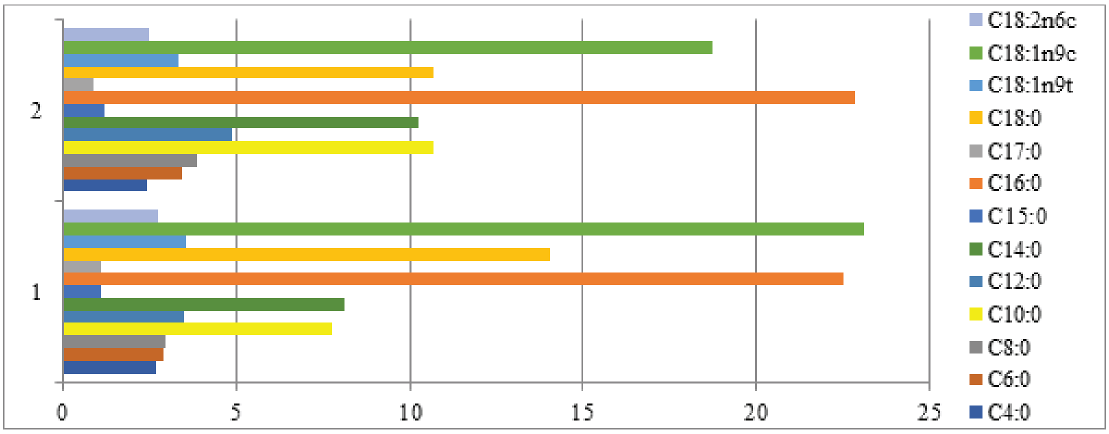

Figure 2: Fatty-acid profile of: 1 -- goat's and sheep's milk mixture in a ratio of 1:1; 2 -- yogurt produced from goat's and sheep's milk mixture .

trend was observed with respect to stearic (C18:0) fatty acid, its decrease is 4.5%. In yogurt, an increase in myristin acid (C: 14) by 2.1%; caprine acid (C10: 0) by 2.9% was noted.

On the basis of data on the fatty acid composition, the atherogenicity index and thrombogenic index (Figure 3) characterizing the quality of fat phase lipids of goat's and sheep's milk and yogurt produced on their basis were calculated. The atherogenicity index indicates the correlation between the sum of the essential saturated fatty acids and the main unsaturated group, the first being considered proatherogenic (promoting the adhesion of lipids to the cells of the immunological and circulatory systems), and the second group is regarded as antiatherogenic (inhibits aggregation and reduces the levels of esterified fatty acids, cholesterol and phospholipids, thereby preventing the emergence of micro - and macro-coronary diseases) [11--14].

The thrombogenicity index shows a tendency to clot formation in blood vessels. This is defined as the relationship between prothrombogenetic (saturated) and antithrombogenetic fatty acids (monounsaturated fatty acids, polyunsaturated fatty acids ω-6 and ω-3) [14--17].

Goat's milk had the lowest index of atherogenicity and thrombogenicity. The atherogenicity index for goat milk was 1.48, thrombogenic index - 2.66. Normally, the ratio of atherogenic and antiatherogenic lipids should not exceed 3.5. Yogurt produced from a mixture of goats' and sheep's milk was characterized by a higher thrombogenic and atherogenic indices than the raw milk. For yogurt from a mixture of goat and sheep milk, the atherogenicity index was 2.44, the thrombogenic index was 3.2. An increase in the value of the atherogenicity index and thrombogenic index characterizes an increase in the degree of risk to human health, as a result of systematic use of the product in question [18, 19, 20]. The obtained results characterizing the changes in the atherogenic

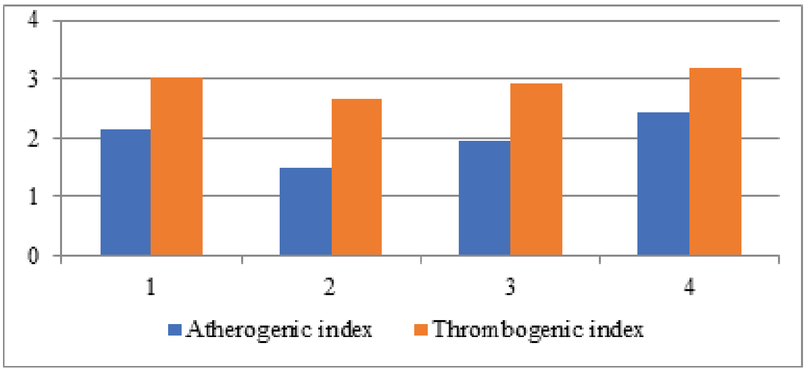

Figure 3: Atherogenic index and thrombogenic index of: 1 -- sheep's milk; 2 -- goat's milk; 3 -- goat's and sheep's milk mixture in a ratio of 1:1; 4 -- yogurt produced from goat's and sheep's milk mixture.

and thrombogenic indices in the milk mixture and the finished product are associated with the activity process of the fermenting microflora. In the process of maturation, there is an increase in the number of saturated fatty acids with a parallel decrease in the concentration of monosaturated and polyunsaturated fatty acids. Figure 4 shows the dynamics of changes in the composition of fatty acids during the production process and as a result of seven-day storage.

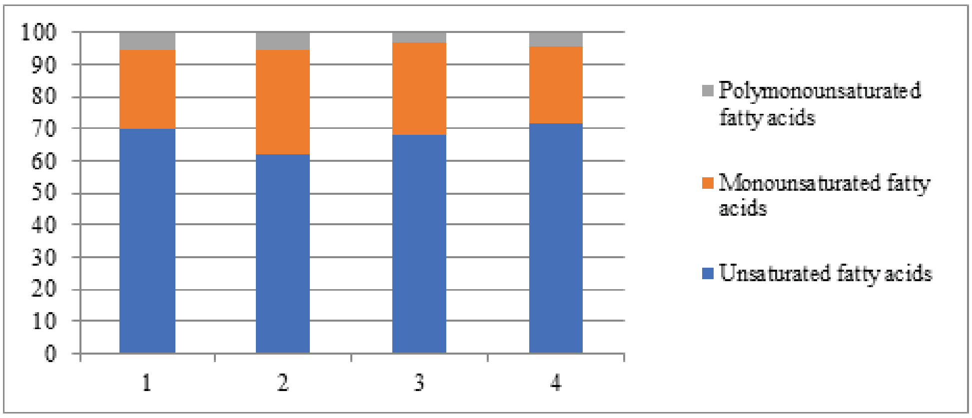

Figure 4: Changing the correlation among saturated, polyunsaturated and monounsaturated fatty acids in the production and storage of: 1 --sheep's milk; 2 -- goat's milk; 3 -- goat's and sheep's milk mixture and 4 -- yogurt produced from goat's and sheep's milk mixture.

The data presented in Figure 4 indicate that during the production of yogurt from a mixture of goat's and sheep's milk, the content of mono- polyunsaturated fatty acids decreases. Goat's milk contains 12% less saturated fatty acids than sheep's milk. As a result of the technological process and the seven-day storage, the amount of saturated fatty acids in yogurt produced from a mixture of goat's and sheep's milk increased by 5%, compared to the original milk mixture. The inverse correlation was observed in the dynamics of polyunsaturated fatty acids in yogurt, as a result of technological processing of the milk mixture and seven-day storage. The content of polyunsaturated fatty acids decreased by 19.27 %. Currently, it is generally recognized that saturated fatty acids and animal fats containing them increase the level of total cholesterol in the blood and cause the development of atherosclerosis.

4. Discussion

The saturated palmitic acid, which accounts for 25% of all fatty acids of animal fats, such saturated fatty acids as lauric (12:0) and myristic (14:0) and also stearic acid produce a hypocholesterolemic effect. It is proposed [11] to use the correlation between polyunsaturated fatty acids (PUFA) and saturated fatty acids in the diet as a factor predicting the impact of the diet on the level of cholesterol in blood plasma.

On the basis of the obtained data, the correlation between hypocholesterolemic and hypercholesterolemic fatty acids in the resource milk raw materials and yogurt produced from a mixture of goat's and sheep's milk in the ratio of 1:1 was identified (Table 1).

Table 1: Correlation between hypocholesterolemic and hypercholesterolemic fatty acids (h/H) in the resource milk raw materials and yogurt.

Name of the indicator	Sheep's milk	Goat's milk	Goat's and sheep's milk mixture	Yogurt
h/H	0,858	1,156	0,980	0,8834

The highest value of the correlation between hypocholesterolemic and hypercholesterolemic fatty acids was noted in goat milk. As a result of the technological process and the seven-day shelf life, the correlation between hypocholesterolemic and hypercholesterolemic fatty acids decreases in yogurt from a mixture of goat's and sheep's milk.

5. Conclusion

The use of goat milk in the milk mixture for the production of yogurt increases the amount of monounsaturated and polyunsaturated fatty acids. However, there is a general tendency to reduce the amount of monounsaturated and polyunsaturated fatty acids in the production and storage of yogurt, with a parallel increase in the content of saturated fatty acids. Goat's milk compared to sheep's milk has a lower value of the atherogenicity and thrombogenic indices. Calculation of atherogenicity index and thrombogenic index is additional information about the functional properties of the product. The identified properties of the fatty-acid profile and its transformation in the yoghurt production process provide an information basis for obtaining qualitatively new fermented milk drinks with a fatty-acid profile favorable for human health.

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Conflict of Interest

The authors have no conflict of interest to declare.

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