Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 4, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

INFLUENCE OF THE SEASON AND GENOTYPE OF GOATS ON THE QUALITATIVE COMPOSITION OF THEIR MILK

Oleksandr KYSELOV*, Oleksandr MYKHALKO*, Larisa BONDARCHUK, Iryna LEVCHENKO**, Mykola PRIHODKO*, Vjacheslav POPSUY***

Sumy National Agrarian University, *Department of Feed Technology and Animal Feeding, **Department of Technology of Production and Livestock Processing and Cynology,160, H. Kondratiiev Street, Sumy, Ukraine, Phones: +38(095)5488087, +38(066)2231449, +38(096)2822483, +38(067)9912896, +38(066)2406516, +38(095)2575308, E-mails: oleksandr.kyselov@snau.edu.ua, oleksandr.mykhalko@snau.edu.ua, bondlara10@gmail.com, irunalevchenko@ukr.net, nikprihodk@gmail.com, vvp72@ukr.net

Corresponding author: snau.cz@ukr.net

Abstract

To study the effect of seasonality and genotype on the productivity of goats and the quality of their milk, 30 goats of three different breeds were taken: 10 Saanen goats, 10 Russian white goats and 10 local Ukrainian goats. The milk yield of the experimental goats was evaluated during the year for the volume, protein content, fat content, lactose content, acidity and density. The effect of both genotype and season on protein content, and the effect of only season on fat content and lactose content were determined. The most dependent on seasonal factors (change of season, temperature fluctuations, amount of precipitation) were goats of Saanen and Russian white breed, the least dependent were goats of local Ukrainian selection. Acidity and density of milk did not change during the entire experiment. The highest protein content (3.32%) and fat content (3.37%) were found in Saanen goats. The highest lactose content (4.53%) was found in goats of local Ukrainian breeding. During the spring and summer months, goats of local Ukrainian selection and Russian white showed the best productivity.Goats of the Saanen breed had the best productivity during the autumn and winter months.

Key words*: *goat's milk, fatty acid composition, seasonal effects, milk productivity of goats

INTRODUCTION

The global goat population continues to grow and currently exceeds one billion. The number of goats raised primarily for milk production is also increasing due to increased demand [30]. In European countries, the share of goat milk is about 30% of the total amount of milk produced, and in Arab countries it reaches 50% or more [13]. In recent years, there has also been a trend towards increasing demand for goat's milk in Ukraine. Since 2011, there has been an increase in the number of goats [40]. The leading place in the world belongs to dairy and combined dairy, and meat breeds at 37% and 20% respectively of the total number of breeds. At the same time, milk (66.4%) and milk-meat (15.9%) goat breeds predominate in Europe, and combined make up more than 50% in Asia and Africa. The largest number of breeds, 374, come from Europe, of which 59 are from Italy, 27 from Germany, 23 from Spain, 20 from Great Britain and 18 from France [41].

The positive effect of goat's milk on human health has long been known, and today its study is deepening. This product has excellent nutritional properties, is easily absorbed by the body, and the complete protein composition ensures the maximum use of essential amino acids to meet the anabolic needs of the body [26]. It has been proven that the composition of fatty acids in goat milk affects human health and directly affects the taste of dairy products [10, 11, 37]. In particular, it was previously reported, that saturated fatty acids increase the likelihood of cardiovascular disease. In addition, it is known that conjugated linoleic acid reduces the generation of cancer cells and inhibits atherosclerosis and diabetes [4]. In addition, a higher amount of some short-chain fatty acids enhances the goat scent and the aftertaste of dairy products [14, 38].

Animals of the *Saanen* breed and its crossbreeds with local goats represent most of the dairy goats in Ukraine. However, there are few purebred goats of the *Saanen* breed [12]. *Saanen* goats are considered one of the most productive dairy goat breeds in the world. With good care and feeding conditions, *Saanen* goats over 2.5 years of age can give a total of 700–900 liters of milk per milking during the lactation period [9]. At the same time, there is information about a large number of local crossbreed goats both abroad and in Ukraine, the productive characteristics and quality of milk of which, compared to goats of common breeds, under certain conditions prevail over the latter [27]. Despite the proven facts of the high productive qualities of goats of known breeds, there are alternative studies that have established the superiority of local goats, in particular alpine goats, over analogues of the *Saanen* breed. According to data [42], goats of the specified breeds had differences in the list of chemical components. Goats of the *Alpine* breed prevailed over goats of the *Saanen* breed both in terms of protein content by 1.33 g/100 g, fat content by 1.45 g/100 g, and ash content by 0.06 g/100 g, respectively, and they also prevailed by profiles fatty acids. Similar conclusions were reached by other scientists, who noted that the milk of Mediterranean red and Ionica breeds was richer in phosphorus (P) than in Maltese and in zinc (Zn) than in Maltese, Girgentan and *Saanen* breeds [6]. In addition, similar results are noted for the peculiarities of local Ukrainian goats improved by the *Saanen* breed, in which the content of fat, protein and dry matter was higher by 1.63, 1.52 and 2.95%, respectively, compared to the production of purebred goats of the *Saanen* breed [32]. The economic effect of introducing the use of local goats is more pronounced in countries with a lower income level of the population, where their breeding allows the maintenance of the income level of households and provides the population with inexpensive products [24]. It is known that the characteristics of local goats allow them to be kept in areas with a difficult arid, mountainous or tropical climate, where the placement and breeding of purebred goats will not have a consistently high result due to their insufficient adaptation [3]. Usually, in countries where goat breeding is widespread, high adaptability to the environment is one of the main characteristics of local goat breeds and crossbreeds, in developed countries most goats have genetically selected breeds for high productivity [31].

Productivity and quality of milk, meat, wool and other products of both purebred and cross-breed goats depend on the same factors. However, the strength of the relationship between factor and dependent features will be significantly different for different combinations of them. Determining the most influential factors that have the most significant impact among others will intensify the production of goat products. However, many scientists have their own vision of this issue and, accordingly, obtain results that do not completely satisfy both manufacturers and the scientific community and, accordingly, encourage further multifaceted research.

Thus, we can note that there is still no unanimous view on the detection, assessment and peculiarities of possible dependence between the quality indicators of milk of purebred and crossbred goats and the known factors influencing them.

The purpose of the study was to compare the dependence of quality indicators of milk raw materials obtained from different cross-breed goats of Ukrainian origin, and seasonal local factors, taking into account the influence of genotypic characteristics of the experimental herd.

MATERIALS AND METHODS

Biological material

To solve the tasks set in the work, a scientific research experiment was conducted to determine the quality indicators of milk raw materials obtained from goats of different breeds, taking into account the season of the year and changing weather conditions (global warming).

The object of our research were lactating goats of local Ukrainian selection (Group I), Russian white breed (Group II) and *Saanen* goats (Group III) in the amount of 10 heads in each group. Goats were kept in experimental conditions of a separate room (vivarium) on the territory of Sumy National Agrarian University, Sumy region, Ukraine. The vivarium we use is intended for growing and breeding laboratory animals, including goats used in scientific work or the educational process. The premises are provided with conditions for humane maintenance, which includes feeding, drinking, maintaining favorable healthy exercise and lactation, maintaining microclimate parameters within the approved norms. When selecting goats for the experiment, the generally accepted principle of matching pairs was followed by age, live weight, and term of the goats. Each of the groups of goats was kept in identical conditions before and during the experiment.

For this study, goats with an average live weight of 58.7–61.5 kg, milk productivity per lactation 691.81–725.23 kg, and a yield of kids per 100 ewes of 175–180% were selected. All procedures were carried out in accordance with the guidelines of the Council Directive 86/609/EEC [5] on the protection of animals used for experimental and other scientific purposes.

Feeding and rearing conditions

In the vivarium, goats were kept on deep litter, the floor area per head was 1.10–1.15 m^2. Animals had constant access to fresh water.

Goats were fed according to the norms of vivarium rations, which provided the following indicators:

1.The structure of the diet for three groups of lactating goats at vivarium was: rough – 27%, juicy – 49%, concentrated – 24%;

2.The level of digestible protein per 1 feed unit (Metabolizable Energy (ME)) was 110.5 g;

3.The energy content of rough age is 0.5 fodder unit (Metabolizable Energy (ME)) (26%), juicy feed was 0.4 feed unit (21%) and concentrated feed was 1.0 feed unit (53%);

4.Feed price was 0.62 (€/kg) for the production of 1 kg of milk;

5. Feed cost was 0.94 (€/kg);

6.The level of dry matter based on 100 kg of live weight was 3.3 kg;

7.Energy nutritional value of dry matter of the diet was 1.0 foodunits (MetabolizableEnergy-ME);

8. The ratio of calcium to phosphorus was 1.5:1.

Analysis of the physical indicators

Milk productivity was determined by daily milking followed by monthly and lactation calculations in mid-April and mid-May. Duration of lactation of goats was 305 days. Milksamplesweretakenfromgoatsaccordingto ISO 707:2008 [19]. Samples of milk taken in proportion to the daily milk yield in 2 adjacent days from each of the experimental groups on the farm were filtered and cooled to a temperature of +6±2ºC and analyzed within 24 hours after milking. Milk samples were taken exclusively from healthy goats that did not show any symptoms of possible diseases.

Analysis of the chemical indicators

Samples for assessing the quality of milk were taken during each of the four seasons of the year twice a month.

The study of the chemical composition of milk was carried out at the testing center of the Animal Husbandry Institute of the National Academy of Sciences, which is accredited according to the requirements of ISO/IEC 17025:2006) [16], certificate No. 2T621 at the National Accreditation Agency of Ukraine. In order to evaluate the energy value of milk and its technological properties, its chemical composition was determined. In the laboratory of the institute, milk samples were heated to a temperature of +40 ºC, homogenized on the device Milk Homogeniser HF-0.5/25 (OHFU, China), which is certified according to ISO 9001:2008 [22]. The chemical composition of milk based on the content of mass fraction (mol) of dry matter (DM), fat (F), true protein and total protein, lactose, dry fat residue (DFR) was determined by infrared spectrometry (ISO 9622:1999) [23]. The reference methods for calibrating the infrared analyzer Thermo Nicolet NEXUS 670 (GMI, USA) according to mass fractions fat content was determined according to ISO 18252:2006 [15]. Total and true protein content was determined according to Kjeldahl method (ISO 8968-1:2014, ISO 8968-5: 2001) [20, 21]. Lactose content was determined according to method of high-performance liquid chromatography (ISO 22662:2007) [17]. Dry matter content was determined accordingto ISO 6731:2010 [18]. The expanded uncertainty of U measurements at calibration k = 2, p = 0.95 was 0.06, respectively; 0.04, 0.03, 0.12 and 0.08%.

Based on the obtained data, the ratio of nutrients in milk, which characterize its technological properties, was calculated and the energy value of milk raw materials was estimated, based on the fact that 1 kg of milk contains 9.5 g fat, 4.4 g protein, 3.74 g lactose. Also, during the experiment, the peculiarities of the influence of weather factors on the milk productivity of goats of the *Saanen* breed, Russian white breed and goats of local Ukrainian selection were studied, namely the following weather factors were studied: air temperature and precipitation.

Statistical analysis

We analyzed the results of our research in the MS Excel 2010 editor using common statistical procedures, two-factor analysis of variance and construction of a mathematical model using the method of the smallest frames. All indicators (n = 24) were compared using Student's t-test. The significance of the differences was confirmed under the condition of $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$.

Ethical approval

During the experiment, we used appropriate methods of treating goats to reduce their pain or discomfort. The recommendations of the International Committee on Animal Ethics and the requirements of the Law of Ukraine No. 692 of 2008 "On Humane Treatment of Animals" and the Law of Ukraine No. 3447-IV of 2006 "On Protection of Animals from Cruelty" were taken into account when conducting the experiment. The university's control body of Ethical and Humane Treatment of Animals in Scientific Research granted permission to use goats (BT-21-0210-02).

RESULTS AND DISCUSSIONS

According to its physico-chemical and microbiological indicators, goat milk has a rather complex structure and is significantly different from the milk raw materials of other animals. Goat milk is a complex polydisperse system in which water is the dispersion medium. Most of the nutritional components of goat's milk are in various colloidal, emulsion and molecular states. Ionic solutions of goat milk consist of milk sugar and mineral components. Breed, lactation characteristics of goats and seasonal factors affect the content of proteins, fats and lactose in goat milk.

Better absorption of goat's milk in the human gastrointestinal tract is due to the size of its fat globules (with a size of 2 µm). Thus, breed composition and genetic features, as well as environmental conditions significantly affect the milk productivity of dairy goats.

Our research shows that in April, the first month of lactation, fluctuations in the ambient temperature of 13°C (from +8 to +21°C) were observed (Fig. 1).

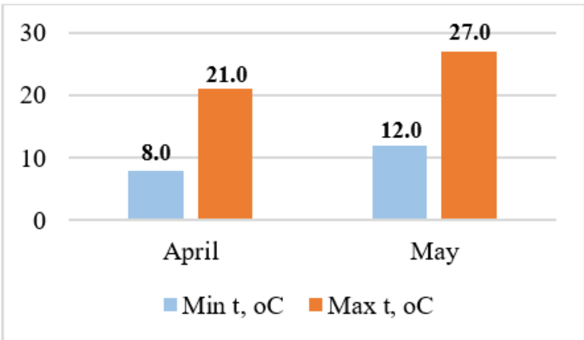

Fig. 1. Temperature extremes of the studied period (^{0}C)
Source: Own calculations.

Fluctuations in average daily milk yield in the control group of goat amounted to 1.21 kg (from 1.45 to 2.66 kg), in the II experimental group 1.25 kg (from 1.50 to 2.75 kg), in the III experimental group 1.31 kg (from 1.55 to 2.86 kg).

The maximum daily yield in the control group I was noted at an ambient temperature of +20°C, in the II experimental group at +19°C, in the III experimental group at +18°C. The minimum daily yield in the control group was recorded at a temperature of +9°C, in the II experimental group – at +10°C, in the III experimental group at +8°C (Fig. 2). In May, in the second month of lactation, daily temperature fluctuations of the environment were 15°C – from +12 to +27°C. Fluctuations in average daily milk yield in the control group of goats amounted to 1.28 kg (from 1.61 to 2.89 kg), in the II experimental group – 1.03 kg (from 1.99 to 3.02 kg), in the III experimental group – 1.01 (from 2.01 to 3.02 kg). The minimum production of goats of the control and experimental groups was noted at a temperature of +12°C, the maximum was noted at a temperature of +25°C in goats of the control group and at +23°C in goats of the II research group and at +21 °C in goats of the III research group (Fig. 2).

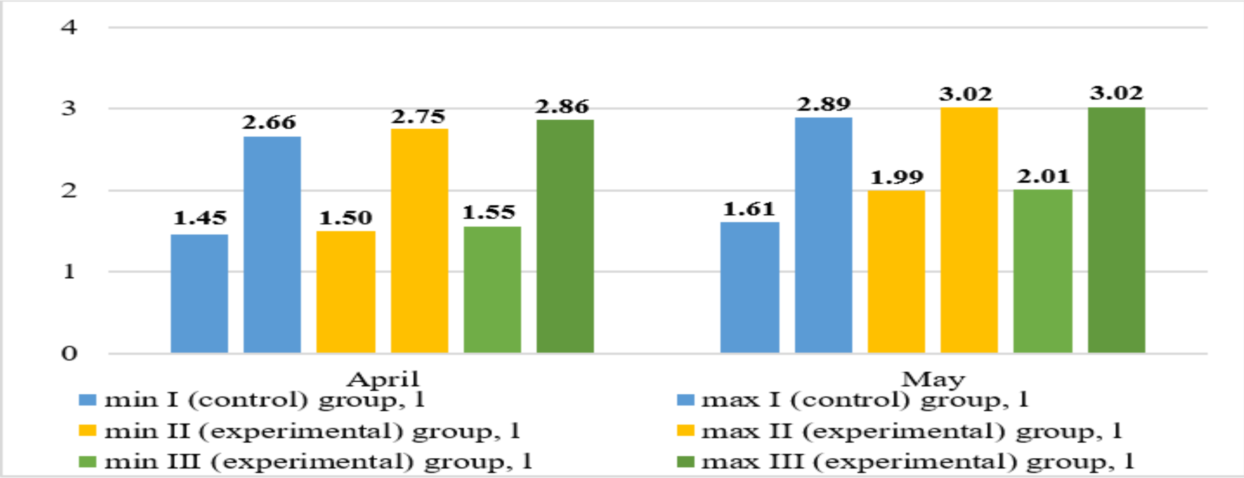

Fig. 2. Extremes of milk productivity of goats under the influence of temperature fluctuations
Source: Own calculations.

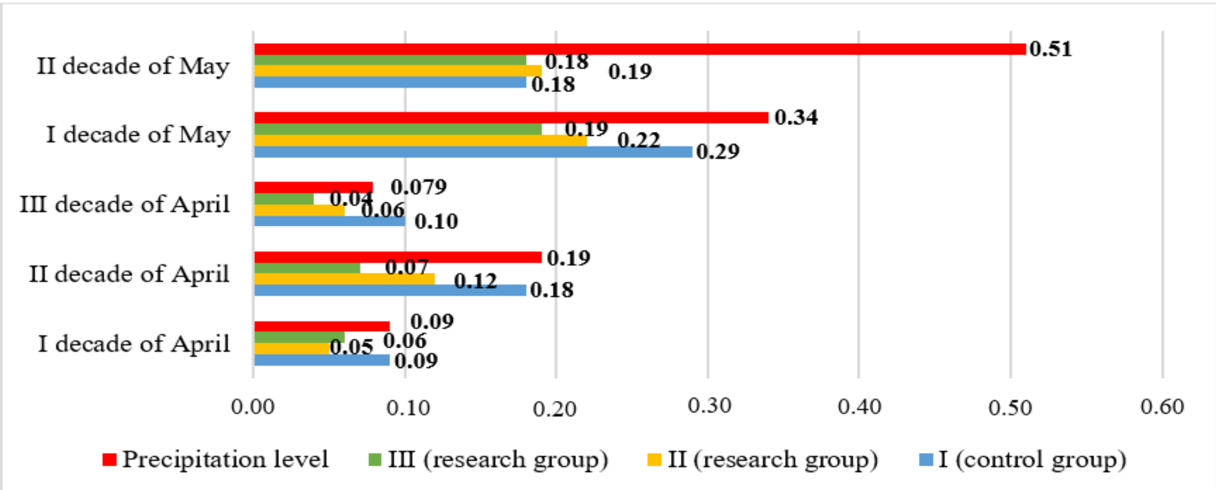

Fig. 3. Dynamics of milk productivity of goats during precipitation
Source: Own calculations.

The decrease in milk productivity, regardless of the ambient temperature, was influenced by atmospheric precipitation (Fig. 3).

Precipitation in the first decade of April did not exceed 9.0 mm. At this time, the average milk yield of goats local Ukrainian selection decreased by 0.09 kg. Goats of the Russian white breed also showed a decrease in milk yield in this decade by 0.05 kg. A similar tendency towards a decline in milk yield was also manifested in the herd of *Saanen* breed by 0.06 kg.

Milk yields of goats remained low during the 2nd decade in response to a gradual increase in precipitation to 19 mm.

Goats of the local Ukrainian selection had this amount of milk for 10 days at the level of 0.18 kg, which was more than Russian white counterparts by 0.06 kg and more than peers of local *Saanen* breed by 0.11 kg.

In the third decade of April, there was a decrease in precipitation to 7.9 mm, as a result of which there was a less significant decrease in milk yield, in particular, in goats of the *Saanen* breed by 0.1 kg, in their counterparts of the Russian white and local breeds of Ukrainian selection by 0.06 and 0.04 kg respectively.

In May, there was a seasonal increase in precipitation, and in the first decade of the month, its level was already 0.34 mm. At the same time, there was a decrease in the milk productivity of goats in the control group to 0.29 kg, in the II experimental group to 0.22 kg, and in the III experimental group to 0.19 kg. During the second decade of May, the tendency to increase the amount of precipitation remained. Rainfall was recorded at 51 mm over 10 days. At the same time, the experimental herd showed a decrease in average milk yield, but with a lower intensity, as there was a gradual increase in temperature in this decade of the month, compared to previous periods, which had a positive effect on milk yield indicators. But all the same, goats of the *Saanen* breed showed a decrease in milk yield by 0.18 kg, their peers of the Russian white breed reacted with a decrease of 0.19 kg, and ewes of the Ukrainian breed of local selection did not give 0.18 kg of milk.

Thus, we can state that with an increase in the amount of precipitation, the lactation of goats was characterized by a decrease in the volume of milk. Goats of the *Saanen* breed reacted more sensitively to an increase in the level of precipitation and showed the highest values of insufficient milk, at the same time, their counterparts of Ukrainian local selection were less affected by weather seasonal fluctuations and reduced productivity the least among animals of the three groups. Therefore, during the work on increasing the yield of dairy goats, natural and climatic factors should be taken into account. This is especially relevant when goats are kept using a grazing system, and when planning to increase milk yield, the influence of such factors as environmental temperature and precipitation should be minimized as much as possible. Therefore, in bad weather, it is advisable to additionally feed goats indoors or under a canopy to avoid a sharp decrease in milk yield.

Analyzing the data in the table. 1, it should be noted that in a temperate climate at the end of summer, goat milk has the lowest levels of fat and protein and the highest levels of active acidity. Research has established that the *Saanen* breed of goats had the highest protein content recorded in autumn 3.46%, which is higher than spring milk by 0.14% ($p < 0.001$), summer milk by 0.30% ($p < 0.001$) and winter milk by 0.12% ($p < 0.001$). The fat content in the milk of goats of local Ukrainian breeding was higher in the fall (3.52%) compared to the spring months by 0.11% ($p < 0.001$), compared to the summer months by 0.74% ($p < 0.001$) and compared to the winter months by 0.17 % ($p < 0.001$). Goats of the I control group showed the highest lactose content in the cold winter season (4.45%). This was higher than the spring season by 0.04% ($p < 0.001$), higher than the summer season by 0.09% ($p < 0.001$) and higher than the autumn season by 0.14% ($p < 0.001$). The protein content in the milk of goats of the Russian white breed reached in the fall exceeded the indicator of the spring season by 0.13% ($p < 0.001$), exceeded the indicator of the summer season by 0.28% ($p < 0.001$), and exceeded the indicator of the winter season by a 0.08% ($p < 0.001$). Goats of the Russian white breed showed the highest fat content in the autumn months compared to the spring months by 0.30% ($p < 0.001$), compared to the summer months by 0.78% ($p < 0.001$) and compared to the winter months by 0.33 % ($p < 0.001$). The highest lactose content was found in goats of this breed in the winter season (4.55%), which was higher compared to spring indicators by 0.03% ($p < 0.001$), summer indicators by 0.05% ($p < 0.001$), autumn indicators by 0.08% ($p < 0.001$).

The protein content in the milk of goats of local Ukrainian selection in the spring was lower than in the autumn by 0.14% ($p < 0.001$), in the summer it was inferior to the autumn indicators by 0.31% ($p < 0.001$), and in the winter it lagged behind the winter protein content by 0.10% ($p < 0.001$).

The milk of goats of the *Saanen* breed had a fat content greater than the fat content during the spring season by 0.11% (p <0.001), higher than in the summer months by 0.75% (p <0.001) and higher compared to the winter indicators by 0.16% (p<0.001).

Saanen breed goats also showed a higher lactose content in winter relative to spring content by 0.04% (p <0.001), relative to summer content by 0.09% (p <0.001), relative to autumn content by 0.14% (p <0.001). So, on average, the protein content during the year changes by 0.08–0.31%, the fat content by 0.11–0.78%, the lactose content by 0.03–0.14%. At the same time, the protein content and lactose content are subject to smaller changes during the seasons of the year, since these components of milk are more thinly and evenly dispersed compared to the fat content. Fatcontent (0.11–0.78%) undergoes the biggest changes according to the seasons of the year. Protein content and lactose content change less, since these components of milk are more thinly and evenly dispersed compared to fat content, and their changes are less influenced by paratype factors. The percentage of protein content ranges from 0.08 to 0.31%, and the lactose content varies from 0.03 to 0.14%. Acidity and density of milk almost do not change depending on the season.

Table 1. Seasonal changes in goat milk indicators (n = 24)

Indicator	Season			
	spring	**summer**	**autumn**	**winter**
Group I (Ukrainian selection local goats)				
Protein content, %	3.00±0.0010^{***b}	2.83±0.0011	3.14±0.0016^{***acd}	3.04±0.004^{**a***b}
Fat content, %	3.41±0.0015^{***bd}	2.77±0.0013	3.52±0.0018^{***abd}	3.36±0.002^{***b}
Lactose content, %	4.53±0.0013^{**b***c}	4.49±0.009	4.45±0.0011^{***b}	4.56±0.009^{**a***bc}
Acidity, °T	14–15	15–16	14–15	14–15
Density, g/cm^3	1.028–1.029	1.026–1.027	1.026–1.027	1.028–1.029
Group II (Russian white goats)				
Protein content, %	3.24±0.008^{***b}	3.09±0.0010	3.37±0.008^{***abd}	3.29±0.006^{***ab}
Fat content, %	3.33±0.0012^{***bd}	2.85±0.0013	3.63±0.0016^{***abd}	3.30±0.008^{***b}
Lactose content, %	4.2±0.0012^{***bc}	4.50±0.0011^{***c}	4.7±0.0015	4.55±0.003^{***abc}
Acidity, °T	14–16	14–15	15–16	14–16
Density, g/cm^3	1.027–1.028	1.026–1.027	1.026–1.027	1.027–1.028
Group III (*Saanen* goats)				
Protein content, %	3.32±0.011^{***b}	3.16±0.009	3.46±0.006^{***abd}	3.34±0.004
Fat content, %	3.51±0.013^{***b**d}	2.88±0.012	3.62±0.021^{***abd}	3.45±0.008^{***b}
Lactose content, %	4.50±0.008^{**b***c}	4.45±0.009^{**d}	4.40±0.010	4.54±0.003^{***abc}
Acidity, °T	14–16	15–16	14–16	15–16
Density, g/cm^3	1.028–1.029	1.026–1.027	1.026–1.027	1.028–1.029

* – P < 0.05; ** – P < 0.01; *** – P < 0.001;
Source: own calculations.

Using two-factor analysis of variance, the influence of genetic belonging to the three experimental groups and the influence of seasonal factors on the protein content of milk was determined. It was established that the factor of the season reliably influenced the protein content (F_{season} 296.84>$F_{-critical}$ 2.61) with a power of 26.46%. The influence of goat breed on milk protein content was also statistically probable (F_{season} 701.32>$F_{-critical}$ 3.00), which formed a dependent trait at the level of 41.67%. The interaction of the specified factors did not have a reliable effect on the amount of protein, and other unaccounted factors caused its changes with a strength of 31.73% (Fig. 4). The results of the effect of season and genotype and their interaction on the fat content in goat milk were statistically reliable. Thefatcontentinthemilkoftheexperimentalherd ofgoatsprobably (F_{season} 1013.40>$F_{-critical}$ 2.61) by 71.95% depended on seasonal factors. The factor of influence of the genetic belonging of goats on the fat content had statistical reliability ($F_{genotype}$ 35.42>$F_{-critical}$ 3.00) and influenced the specified indicator with a power of only 1.08%. The influence of the interaction of season and genotype factors on the fat content of goat milk was statistically significant ($F_{\text{-factor interaction}}$ 7.64>$F_{\text{-critical}}$ 2.10) at a level of no more than 1.67%. Ignored factors caused a change in the studied indicator with an influence of 25.27% (Fig. 5).

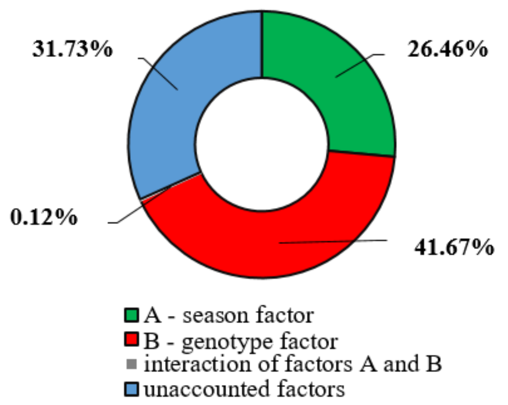

Fig. 4. The influence of season and genotype of goats on protein content
Source: own calculations.

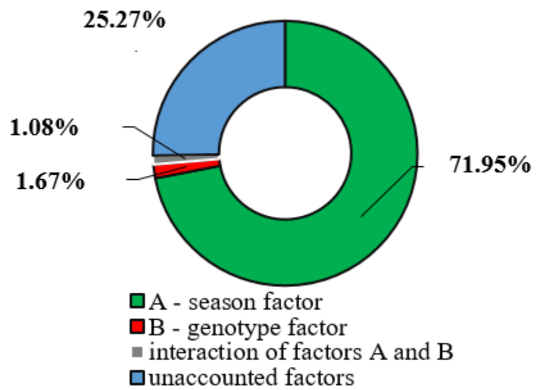

Fig. 5. The influence of season and genotype of goats on fat content
Source: own calculations.

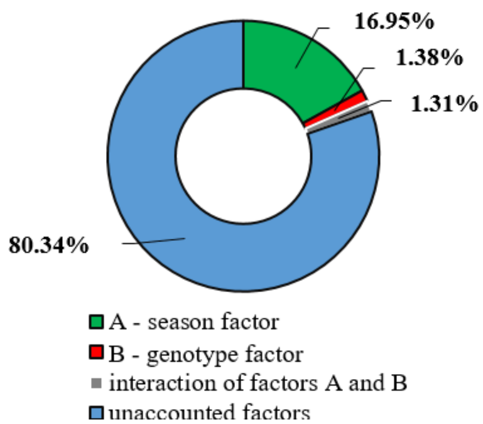

Fig. 6. The influence of season and genotype of goats on lactose content
Source: own calculations.

A probable influence (F_{season} 75.14>$F_{\text{-critical}}$ 2.61) of seasonal factors on the lactose content was established at the level of 16.95%. The effect of the goat genotype on the specified indicator was also statistically confirmed ($F_{genotype}$ 9.18>$F_{\text{-critical}}$ 3.00) and reached a value of 1.31%. The interaction of the factors of the season and breed of goats probably ($F_{\text{-factor interaction}}$ 2.90>$F_{\text{-critical}}$ 2.10) influenced the lactose content in their milk with a force of 1.31%. Ignored factors caused a change in the studied indicator within 80.34% (Fig 6).

Thus, we observe the presence of a confirmed influence of both seasonal and genotypic factors and their interaction on the protein content, fat content and lactose content in the milk of goats of all three groups at once with different strengths, however, it should be noted that on animals of each individual breed they can affect differently.

In order to study the dependence of the content of protein, fat and lactose on seasonal factors, namely, on the influence of the temperature of the natural environment, data analysis was carried out by constructing a two-dimensional linear mathematical model using the method of least squares.

Therefore, using the indicated two-dimensional linear mathematical model built by the method of least squares (Table 2), an analysis of the presence and closeness of the linear relationship between protein content indicators and changes in temperature indicators during the seasons in all experimental goats was carried out. As a result, it was found that in goats of the *Saanen* breed, the relationship between the indicated indicators was not reliable (F_{est} 0.0022<F_{crit} 1.1898), and therefore the dependence of protein content on temperature changes was not confirmed.

At the same time, it was proved that goats of the Russian white breed showed a statistically reliable (F_{est} 1.8530>F_{crit} 1.1898) dependence of the protein content indicator in their milk on temperature fluctuations of the environment, which was confirmed by the value of the pair correlation coefficient, which showed a moderate ($0.3<r_{xy}<0.5$), inverse ($r_{xy}<0$) relationship between indicators for goats of this group. And this shows that with the increase in average daily temperatures, the protein content in the milk of these goats decreases.

At the same time, no statistically significant relationship was established between the protein content in the milk of goats of the Ukrainian local breed and the fluctuation of the temperature regime during the year (F_{est} 01709<F_{crit} 1.1898), which indicates some adaptation of the animals of the specified group to the effect of seasonal factors on the protein content in their milk.

Table 2. Statistical data of a two-dimensional linear mathematical model by the method of least squares

Indicator	Protein content		
	Group I	**Group II**	**Group III**
F estimated value of Fisher's test, F_{est}	0.0022	1.8530	0.1709
F critical, F_{crit}	1.1898	1.1898	1.1898
Pairwise correlation coefficient, r_{xy}	-0.4920	-0.6097	-0.3642
Coefficient of determination, R^2	0.2421	0.3718	0.1309

Source: own calculations.

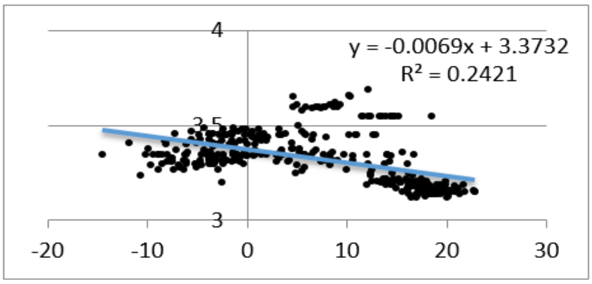

Fig. 7. Linear approximation of the dependence of protein content on changes in average daily temperatures throughout the year in *Saanen* goats
Source: own calculations.

The evaluation of the coefficient of determination based on the established inverse dependence shows that 0.24% of the variance of the effective characteristic of the protein content in the milk of *Saanen* goats could be caused by a change in the factor characteristic: the temperature regime, and the rest of the variance could be caused by the influence of random factors (Fig. 7). The coefficient of the inverse linear regression equation shows that for every 1°C increase in temperature, the protein content could proportionally decrease by 0.0069% (Fig. 7). However, the value of the coefficient of determination was not likely for the mentioned control group, so this is only a guess.

At the same time, the study of the coefficient of determination under confirmed inverse dependence for the population of goats of the Russian white breed allows us to state that 0.37% of the change in the protein content of their milk is caused by the change in temperature indicators during the year, and the remaining 99.63% of the indicator variation is caused by other factors. The analysis of the mathematical expression of the dependence between the specified indicators shows that when the ambient temperature increases by 1°C, the protein content in milk will reliably decrease by 0.0089% (Fig. 8).

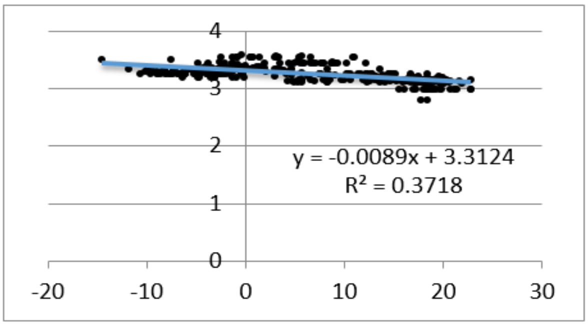

Fig. 8. Linear approximation of the dependence of protein content on changes in average daily temperatures throughout the year in Russian white goats
Source: own calculations.

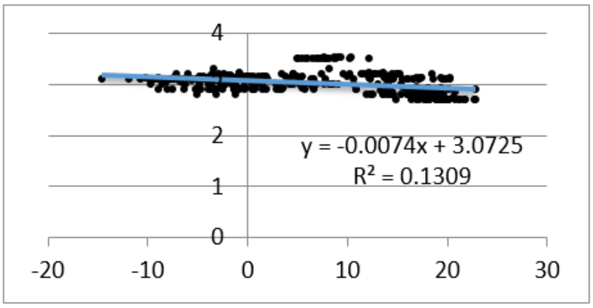

Fig. 9. Linear approximation of the dependence of protein content on changes in average daily temperatures throughout the year in goats of local Ukrainian breeding
Source: own calculations.

The analysis of the coefficient of determination based on the revealed inverse regression showed that 0.13% of the possible protein content in the milk of goats of the Ukrainian local breed could be formed by the effect of the factor of temperature changes during four seasons, if we detected its reliable influence. And according to the values of the coefficient of the inverse linear regression equation, an increase in temperature by 1°C could cause a decrease in the protein content by 0.0074% (Fig. 9), but this judgment cannot go beyond the limits of assumption.

Therefore, we can state that the protein content depended on natural temperature fluctuations only in goats of the Russian white breed, and in goats of the *Saanen* and Ukrainian local breeds, such a dependence was not observed.

The assessment of the interdependence between the fat content in milk and the change in temperature during the studied period showed a noticeable ($0.5<r_{xy}<0.7$), inverse ($r_{xy}<0$) and statistically significant ($F_{est}>F_{crit}$) relationship between the specified indicators for goats of all experimental groups. And this shows that with the increase in the average daily temperature, the fat content in their milk decreases significantly (Table 3).

The found coefficient of determination indicates that for goats of the *Saanen* breed, 0.31% of the changes in the resulting characteristic (fat content) was formed by the behavior of the factor characteristic (by the temperature level), and the rest of the changes depend on unaccounted random factors (Fig. 10).

Table 3. Statistical data of a two-dimensional linear mathematical model by the method of least squares

Indicator	Fat content		
	Group I	Group II	Group III
F estimated value of Fisher's test, F_{est}	10.3338	8.3393	8.2747
F critical, F_{crit}	1.1898	1.1898	1.1898
Pairwise correlation coefficient, r_{xy}	-0.5643	-0.5742	-0.6262
Coefficient of determination, R^2	0.3121	0.3298	0.3922

Source: own calculations.

Observation of the coefficient of the inverse linear regression equation made it possible to state that for each decrease in the ambient temperature by 1°C, the fat content in milk will proportionally increase by 0.0199% (Fig. 10).

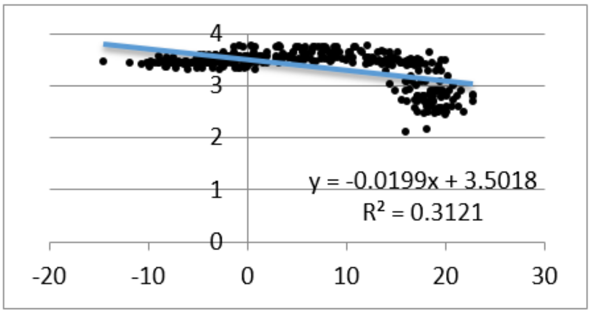

Fig. 10. Linear approximation of the dependence of fat content on changes in average daily temperatures throughout the year in *Saanen* goats
Source: own calculations.

The calculated coefficient of determination for the mathematical expression of the variability of the fat content in the milk of goats of the Russian white breed under the influence of seasonal temperature fluctuations revealed that the dependent trait was formed by the action of the factor by 0.32%, and by the action of other unidentified factors by 99.68%. Taking into account the obtained coefficient of the inverse linear regression equation for this model, we can say that if the external seasonal temperature drops by 1°C, the fat content in the milk of these goats will increase by 0.0199% (Fig. 11).

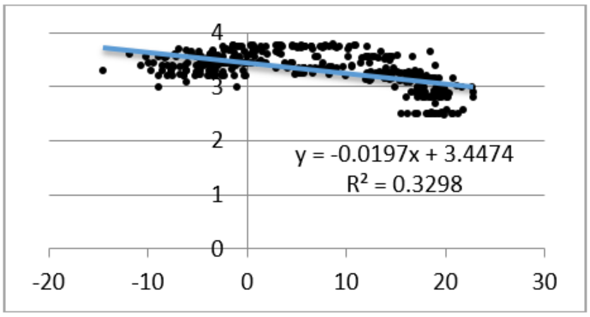

Fig. 11. Linear approximation of the dependence of fat content on changes in average daily temperatures during the year in Russian white goats
Source: own calculations.

The obtained coefficient of determination for the description of the dependence between the fat content in the milk of goats of the Ukrainian local breed and changes in the

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 4, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

external temperature indicates that 0.39% of changes in the dependent characteristic was formed under the influence of the factor, and the rest (99.61%) of its changes was formed under the influence of extraneous, unassessed in this study factors. Calculations of the coefficient of the inverse linear regression equation established that if the natural temperature decreases during the day by 1°C, the fat content in milk will increase by 0.0213% (Fig. 12).

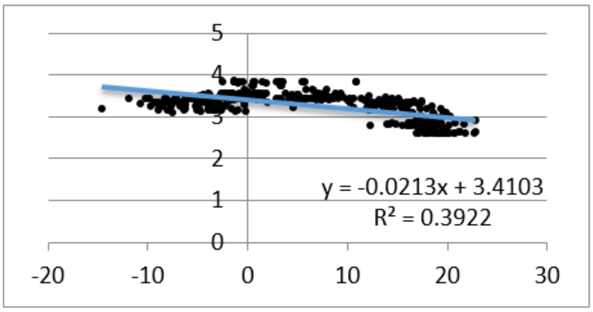

Fig. 12. Linear approximation of the dependence of fat content on changes in average daily temperatures throughout the year in goats of local Ukrainian breeding
Source: own calculations.

Thus, we can say that the fat content in milk depended most strongly on changes in environmental temperature in goats of the Ukrainian local breed, and the least in goats of the *Saanen* breed.

Table 4. Statistical data of a two-dimensional linear mathematical model by the method of least squares

Indicator	Lactose content		
	Group I	Group II	Group III
F estimated value of Fisher's test, F_{est}	1.1327	1.1327	2.7297
F critical, F_{crit}	1.1898	1.1898	1.1898
Pairwise correlation coefficient, r_{xy}	-0.4594	-0.5200	-0.2878
Coefficient of determination, R^2	0.2111	0.2704	0.0828

Source: own calculations.

Further research on the dependence of the content of milk components on changes in the temperature regime during the seasons of the year using a two-dimensional linear mathematical model using the method of least squares (Table 4) revealed a linear relationship between the indicators of the lactose content and temperature fluctuations. At the same time, no statistically significant relationship between dependent and factor traits was established in goats of both the *Saanen* breed and the Russian white (F_{est} 1.1327<F_{crit} 1.1898).

However, it was found that goats of the Ukrainian local breed were distinguished by the presence of a reliable dependence between the lactose content and changes in ambient temperatures (F_{est} 2.7297>F_{crit} 1.1898). And the pairwise correlation coefficient for indicators of the lactose content in the milk of goats of this group showed a weak (0.1<r_{xy}<0.3) and inverse (r_{xy}<0) relationship with fluctuations in daily temperature indicators. And this signals an increase in the level of lactose in milk when the temperature drops.

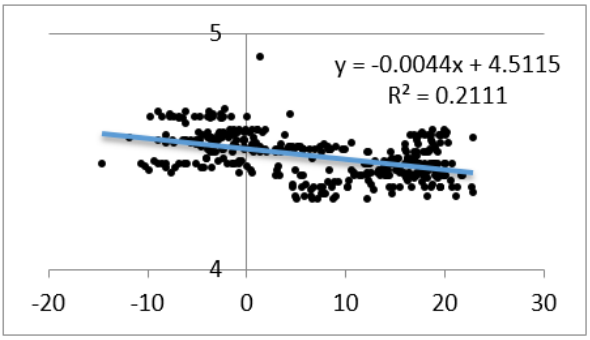

Fig. 13 Linear approximation of the dependence of lactose content on changes in average daily temperatures throughout the year in *Saanen* goats
Source: own calculations.

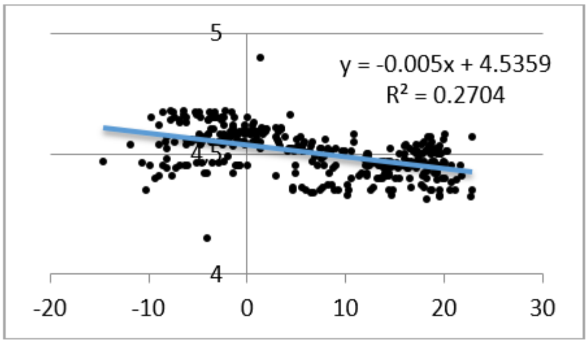

Fig. 14. Linear approximation of the dependence of lactose content on changes in average daily temperatures throughout the year in Russian white goats
Source: own calculations.

The value of the coefficient of determination revealed the potential dependence of the lactose content indicator in the milk of *Saanen* goats by 0.21% (Fig. 13) on the influence of temperature indicators throughout the season.

And changes in temperature by 1°C could lead to changes in lactose content by 0.044%, however, reliable confirmation of such a relationship was not found (Table 4).

The possible dependence of the lactose content in the milk of goats of the Russian white breed on changes in seasonal temperatures could be at the level of 0.27% (Fig. 14), which would be manifested in a symmetrical decrease of the dependent characteristic by 0.005% when the factor characteristic increases by 1°C. But such a potential dependence was not confirmed statistically (Table 4).

The coefficient of determination specified for the dependence of the lactose content in the milk of goats of the Ukrainian local breed on the temperature regime reflected the influence of the factor characteristic on the dependent one at the level of 0.08%, while 99.92% of the remaining changes in the indicator were formed under the influence of extraneous factors (Fig. 15).

The coefficient of the inverse linear regression equation for this model shows that if the daily temperature of the environment decreases by 1°C, the lactose content in the milk of goats of this group will increase by 0.004%.

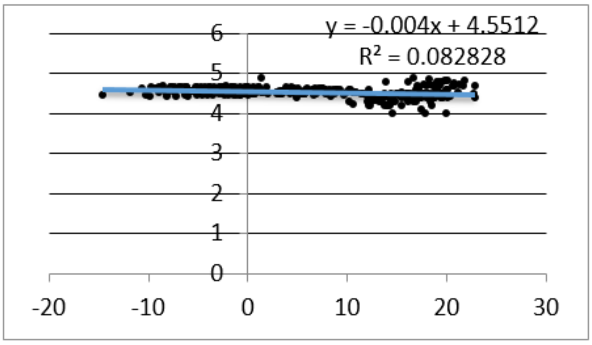

Fig. 15. Linear approximation of the dependence of lactose content on changes in average daily temperatures throughout the year in goats of local Ukrainian breeding
Source: own calculations.

Therefore, the seasonal dynamics of the lactose content in milk was reliably, albeit at a weak level, formed by seasonal temperature fluctuations only in goats of the Ukrainian local breed. In animals of other breeds, the lactose content in their milk did not depend on the temperature factor.

According to the obtained data, we established that goats of the *Saanen* breed in the spring season had higher indicators of protein content and fat content, respectively, by 9.64% ($p<0.001$) and by 2.85% ($p<0.001$), but lower indicators of lactose content at 2.95% ($p<0.001$) relative to goats of the Ukrainian local breed. These results completely contradict other findings [32], which indicated that local Ukrainian goats improved with the *Saanen* breed had higher fat, protein, and dry matter content by 1.63%, 1.52%, and 2.95%, respectively, compared to products of purebred *Saanen* goats. The same identical predominance of *Saanen* goats over Ukrainian local goats was noted in the results of our research during the rest of the year.

In contrast to the publication [29], we found a probable effect of seasonal factors on the lactose content, fat content and protein content of goat milk, which was consistent with reports [25, 34, 44].

Our conclusions did not coincide with the data [35, 39] about the predominance of the influence of genotypic factors on milk productivity of goats, as we established its effect in the range of 1.08–41.67%, which was less than the effect of seasonal factors, which was in in the range of 16.95–71.95%. Although, in general, this result of ours coincided with the opinion [2], which noted the influence of genotype on the content of protein, fat and lactose in goat milk as statistically reliable, but it did not coincide with the essence of another publication [33], which rejected the presence of the influence of the genotype of goats on the specified indicators.

At the same time, the conclusions of our research on the results of factor analysis do not contradict alternative data [1, 7, 8, 28, 36, 43], but indirectly confirm them, since we monitored the influence of unaccounted factors on the composition of goat milk at the level of 25.27–80.34%, among which the influence of the type of feeding and ration, age of goats, number of lactations, stage of lactation, milking time and others remained directly uninvestigated.

Based on the analysis of the closeness of the connection between the influencing feature (seasonal factor) and dependent features (the content of protein, fat and lactose in milk) using a two-dimensional linear mathematical model by the method of least squares, it was established that the connection between them turned out to be weak ($0.1<r_{xy}<0.3$), moderate ($0.3<r_{xy}<0.5$) or noticeable ($0.5<r_{xy}<0.7$). Thus, our data are similar to other published results [25, 34], but the latter spoke about the established relationship of probably high density between the specified features ($0.7<r_{xy}<0.9$).

CONCLUSIONS

As a result of the experiment, it was established that the productivity of goats of the *Saanen* breed, Russian white and local Ukrainian selection, had a tendency to decrease in the cold season and to increase in the warm season.

During the change of seasons, the maximum fluctuations were recorded in the fat index from 0.11% to 0.78%. Indicators of protein content and lactose content showed less variability. The protein content index ranged from 0.08 to 0.31%, and the lactose content ranged from 0.03 to 0.14%. Indicators of acidity and density of the milk almost did not change during the studied period. The highest content of protein and fat in milk was in goats of the *Saanen* breed 3.32% and 3.37%, respectively. The highest lactose content was found in goats of local Ukrainian selection 4.53%.

It was established that the protein content in milk depended on the season by 26.46%, on the genotype by 41.67%, and on unaccounted factors by 31.73%. Fat content depended on seasonal factors by 71.95% and on unaccounted factors by 25.72%. Lactose content depended on the season factor by 16.95% and on unaccounted factors by 80.34%. The statistical analysis of the data by constructing a two-dimensional linear mathematical model using the method of least squares showed that the fat content in milk depended most strongly on changes in the ambient temperature in goats of the Ukrainian local breed, and the least in goats of the *Saanen* breed. The protein content depended on natural temperature fluctuations only in goats of the Russian white breed, and in goats of the *Saanen* and Ukrainian local breeds such a dependence was not observed. The seasonal dynamics of lactose content in milk was reliably, albeit at a weak level, formed by seasonal temperature fluctuations only in goats of the Ukrainian local breed. In animals of other breeds, the lactose content in their milk did not depend on the temperature factor.

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