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# Influence of Diet on the Productivity and Characteristics of Milk of Goats of Different Breeds

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**Key words:** Feeds, milk yield, fat, total protein, somatic cells count

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**Abstract:** We assessed the relationship between the quality of the milk of different breeds of goat and their diets. Anglo-Nubian, German White and Alpine goats were used in the experiment with 7 goats representing each breed. We investigated the influence of two diets: a routine diet (hay and concentrates) and a diet improved by introduction of granulated alfalfa hay, cabbage and carrots as well as mixed feed. After machine milking of each goat the volume of the morning milk yield and biochemical parameters of the milk were measured. When fed the improved diet the milk yield of the Alpine goats increased 3 times and that of the German White goats increased >2.5 times. In the conditions of improved diet the fat content in the milk of goats of all breeds significantly increased. A significant increase in the protein, lactose and consequentially the, dry non-fat milk solids was found in the Anglo-Nubian and German White goats when fed the improved diet. Compared with the German White and Alpine goats, the highest figures for the fat, protein and lactose were found in milk of the Anglo-Nubian goats both with the routine and improved diet. The maximum difference in the biochemical parameters of milk upon changing the diet was also found in Anglo-Nubian goats. With all breeds under study the freezing point and electrical conductivity of the milk decreased when they were fed the improved diet. An inverse relationship was found between the protein content in the goat's milk and the freezing point: with increase in the protein content, the freezing point was reduced.

## INTRODUCTION

Breeding of goats is one of the efficient lines of livestock farming in the world (Haenlein, 2001, 2004; Bernard *et al*., 2009; Boyko, 2015; Boyko *et al*., 2016). It provides people with valuable food products. With regard to Ukraine, dairy products obtained from goats are used only partially. However, consumer interest in goat milk

and products made from it is growing from year to year. Goat milk produced in the world is processed into cheese and other dairy products (Pulina *et al*., 2006; Sampelayo *et al*., 2007; Ollier *et al*., 2009). The biochemical properties of milk (fat and protein concentration) and the somatic cells count are evaluated in terms of dependence of milk quality on the goat's diet (Pulina *et al*., 2006). Length of feed Beauchemin *et al*. (1994), forage-to-concentrate ratio and addition to the basic diet of various additives: sunflower, linseed oils, olive cake (Beauchemin and Buchanan-Smith, 1989; Beauchemin, 1991; Kawas *et al*., 1991; Bava *et al*., 2001; Bernard *et al*., 2005; Min *et al*., 2005; Ollier *et al*., 2009) have an effect on the quantity and quality of the milk. Another important factor which influences milk productivity is the breed of goat. It has been established that fat content in the milk of Saanen goats is higher than in that of Alpine but lower than in Nubian goat's milk. The maximum protein amount is contained in the milk of Nubian goats (Boichard *et al.*, 1989; Yangilar, 2013).

Since, goats of various breeds differ significantly by productivity and composition of milk, there is a need for overall evaluation of these animals for their effective and task-oriented use in milk production.

The Saanen goat is one of the most popular breeds in dairy goat breeding. Along with it, Alpine, Nubian and German White goats are used on some farms. Therefore, the objective of this study is the evaluation of quality of Alpine, Anglo-Nubian and German White goat milk in relationship to the goat diet.

## MATERIALS AND METHODS

**Animals:** The experiment was carried out on "Ukrselkhozprom" farm which is located in Dnipropetrovsk region (the Northern part of the steppe zone of Ukraine) and specializes in goat breeding. The 21 lactating Anglo-Nubian, German White and Alpine goats (7 animals of each breed) were used in the experiment. The goats were imported from Germany during the last 3 years and they are kept in satisfactory conditions. In summer the animals spend all day on the exercising area; in the cold season they stay indoors. The goats have free access to feed and water. Milking is performed twice a day using a milking machine and churn. The goats were of 3-5 lactation. The lactation stage of goats was 5-6 month during the first statistical evaluation.

**Analysis of milk and feed composition:** In our experiment, we monitored the change in the goat's diet: the diet K-legume hay, grain crops and the diet A-meadow hay, granulated alfalfa hay and mixed feed. Milk samples from each animal were taken in August and in October, 2015. After the machine milking of each goat, the volume of the morning milk yield was measured. Then a milk sample (60 mL) was taken from each animal and transported to the laboratory at the temperature of +4°C within two hours after taking samples.

Immediately after the obtaining of samples, the following 11 indices from them were analyzed: fat (%), total protein (%), dry non-fat milk solids (%), lactose (%), density (°A), freezing point (°C), conductivity (mS/cm), pH, acidity (°T), somatic cells count ($10^3$ cells $mL^{-1}$), milk yield (mL). The investigations were conducted at the laboratory of the Department of Parasitology and Veterinary-Sanitary Examination of Dnipropetrovsk State Agrarian-Economic University. The physical and chemical composition of the milk was determined using an ultrasonic milk analyzer Ekomilk Milkana Kam 98-2a (Bulgaria). The bounds of permissible absolute error in measurements of the weight fractions were as follows: fat-±0.1%, total protein-±0.15%, dry non-fat milk solids-±0.2% and for freezing point-±0.01°C, pH-±0.05, density-±0.5°A. The somatic cell count in the milk was determined by a viscosimetric analyzer Somatos-M (Russia). The principle of operation of this device is based on measurement of the relative viscosity (time of capillary flow of the milk sample mixed with the Mastoprim preparation). The Mastoprim preparation destroys the somatic cells and DNA molecules move to the extracellular space changing the relative viscosity. The relative error of viscosity measurement does not exceed 5%.

The quality of the feeds was analyzed at the Scientific Research Centre for Biosafety and Environmental Control of the Agro-Industrial Complex (Dnipropetrovsk State Agrarian-Economic University). The content of 6 components of the feed: crude protein (%), crude fiber (%), crude fat, (%), calcium (g $kg^{-1}$), phosphorus (g $kg^{-1}$), carotene (amount of carotenoids) (mg $kg^{-1}$) was studied. Crude protein was measured by the block digestion and steam distillation method (ISO 5983-2:2009), crude fiber by the method with intermediate filtration (ISO 6865:2000), crude fat by (ISO 6492:1999).

Phosphorus was measured by the spectrometric method (ISO 6491:1998); calcium was determined by the method using atomic absorption spectrometry (ISO 6869:2000). The total amount of carotenoids was determined using the spectrophotometer (SP-2000) at 450 nm; extraction was performed with petroleum ether (Rodriguez-Amaya, 2001).

**Experimental procedure and feed composition:** Before and during the experiment the animals were kept in the stock pen. With the use of the diet K, one goat received per day 4.5 kg of alfalfa hay, 100 g of barley, corn and sunflower meal. The diet A included 2 kg of meadow hay, 2.5 kg of alfalfa hay, 600 g of granulated alfalfa hay and 400 of commercial blend (wheat, sunflower, salt, wheat bran, tricalcium phosphate, chalk feed, premix P 82-1; quality indicators: exchange energy-9.5 MJ $kg^{-1}$, feed unit-89.8%, crude protein-15.0%, crude fat-3.1%, crude fiber-8.1%, Ca-0.8%, P-0.88%, Na-0.44%, Cl-0.64%, NaCl-1.10% as well as vitamins A, E, D and trace elements Cu, Co, S, Fe, Se, J, Zn, Mg), 100 g of fresh carrots and 100 g of fresh cabbage per one animal a day. When analyzing the feeds of the diet K, we found that the maximum indices of crude protein were equal to 32.1% in sunflower meal in corn, alfalfa hay and barley they did not exceed 9.8, 10.5 and 13.6% accordingly. The amount of crude fiber reached maximum values in sunflower meal and alfalfa hay (24.6 and 29.9%) and it was the least in corn and barley (2.8 and 4.9%). The percentage of crude fat in alfalfa hay was 2.7% in barley-2.7% in corn-3.5% and in sunflower meal-14.8%. The content of carotene in alfalfa hay was 8.82 mg $kg^{-1}$ and the content of calcium-5.67 g $kg^{-1}$. Its minimum value was recorded in corn and barley (0.38 and 0.68 g $kg^{-1}$). In alfalfa hay the amount of calcium was 3.04 g $kg^{-1}$. Phosphorus in this diet was in the limits of 1.75-7.41 g $kg^{-1}$. Maximum levels of phosphorus were found in sunflower meal. In corn, barley and alfalfa hay they did not exceed 1.75, 1.91 and 2.84 g $kg^{-1}$ accordingly.

The amounts of crude protein with the diet A were as follows: meadow hay-3.8%, alfalfa hay-14.8%, granulated alfalfa hay-16.3%, mixed feed-15.0%. Indices of crude fiber in the feeds of this diet increased. Their values varied from 29.9-38.3% (with the maximum amount in alfalfa hay and minimum amount in granulated alfalfa hay) in meadow hay this index was 32.7%. Crude fat in granulated alfalfa hay did not exceed 2.9%, in meadow hay-2.0% and in alfalfa hay-1.7%. With this diet, carotene indices in hay reached 11.1 mg $kg^{-1}$ in granulated alfalfa hay-10.8 mg $kg^{-1}$ in meadow hay-3.4 mg $kg^{-1}$. The maximum concentration of calcium was recorded in granulated alfalfa hay-17.6 g $kg^{-1}$ in meadow hay and alfalfa hay-4.1 and 8.7 g $kg^{-1}$ accordingly. Figures for phosphorus in hay varied within the limits of 1.61-2.35 g $kg^{-1}$: meadow hay-1.87, alfalfa hay-2.35, granulated alfalfa hay-1.61 g $kg^{-1}$.

Therefore, taking into account daily consumption of each component in the feeds of the diet A compared with the diet K, the indices of crude protein increased by 0.05%, crude fiber by 6.94%, carotene by 3.67 mg $kg^{-1}$, calcium and phosphorus by 14.91 and 0.22 g $kg^{-1}$ accordingly.

**Statistical analysis:** The data was analyzed by ANOVA using the package Statistica 8.0. Vertical bars (Fig. 1-3) denote 0.95 confidence intervals, small squares on the diagrams show median, large rectangle means 25-75% quartiles, the selected outlier data points (outliers and extremes) are designated as º and *. The threshold of significance for differences in characteristics was set at $p<0.05$. The joint variability of the studied characteristics of milk was analyzed by cluster analysis (Euclidean distance, single linkage) using the package Statistica 8.0 (Fig. 4).

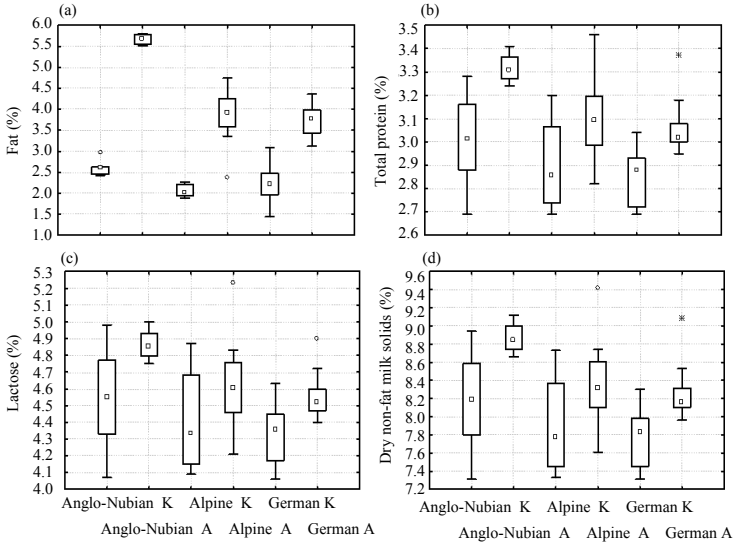


Fig. 1: Continue

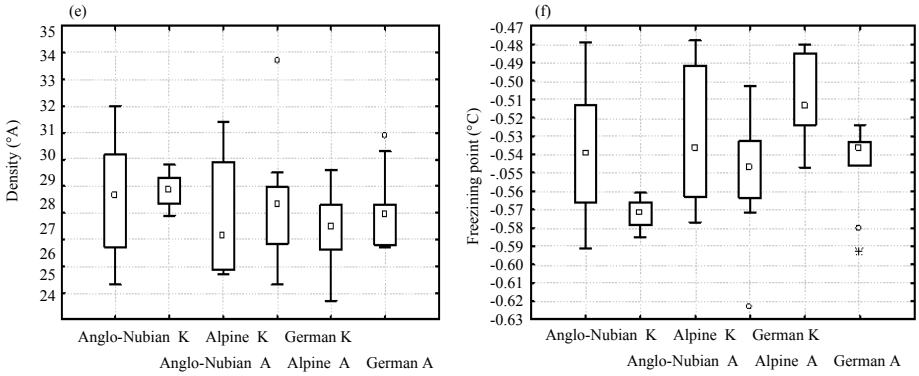


Fig. 1(a-f): Variability of the main characteristics of milk product in three goat breeds, (a) Fat (%), (b) Total protein, (c) Lactose (%), (d) Dry non-fat milk solids (%), (e) Density (°A) and (f) Freezing point (°C); K and A two variants of the goat's diet; n = 7

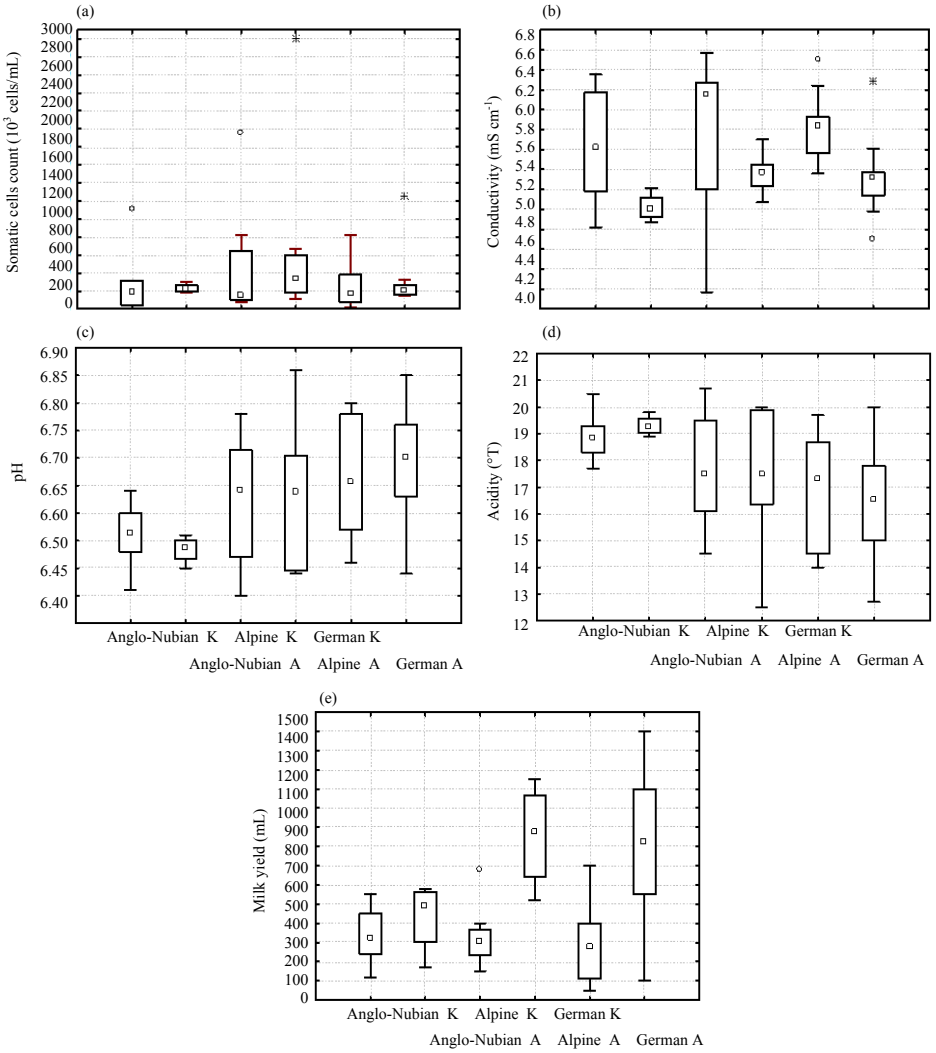


Fig. 2(a-e): Variability of the main characteristics of milk product in three goat breeds: (a) Somatic cells count ($10^3$ cells/mL), (b) Conductivity (mS $cm^{-1}$), (c) pH, (d) Acidity (°T) and (e) Milk yield (mL); K and A two variants of the goat's diet; n = 7

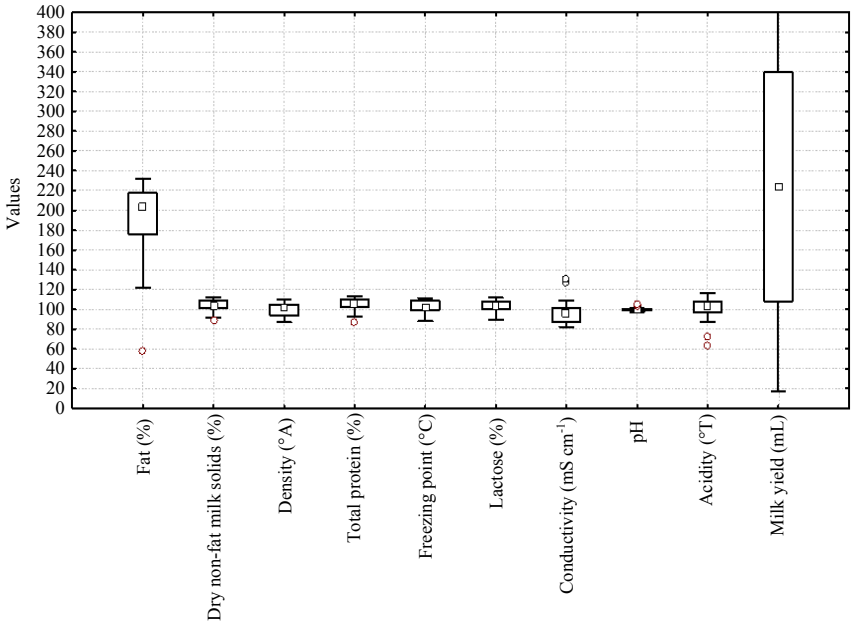


Fig. 3: Mean change in milk characteristic for each individual goat under influence of the improved diet: on the abscissa axis characteristics studied, on the ordinate axis the ratio of value of the characteristic for each individual animal kept on the diet A with regard to values of the characteristic of the same animal for the diet K (%); n = 21

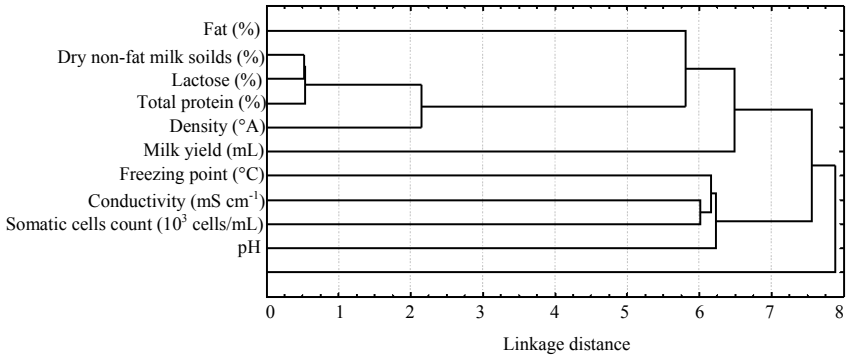


Fig. 4: Results of cluster analysis of studied characteristics of the goat milk

## RESULTS AND DISCUSSION

The fat content of the diet K was significantly lower ($p<0.001$) for all goats under study, because of the low nutritional value of the feeds compared with the diet A. The highest index of fat with the diet K was recorded for the Anglo-Nubian goats-median 2.62% being 0.38% higher than for the German White goats and 0.56% higher than for the Alpine goats (Fig. 1a). This tendency was maintained also in autumn with improvement of the diet: the median of fat content in milk of the Anglo-Nubian goats was 1.86 and 1.93% higher than in the Alpine and German White goats, respectively.

Protein content in goat milk also refers to economically important characteristics (Fig. 1b). Protein content in milk of the Alpine goats on the diets K and A showed no significant difference (medians 2.87 and 3.10%, respectively). The Anglo-Nubian and German White goats showed significant differences ($p<0.01$) in protein content (Fig. 1b): for the first breed the median of the characteristic grew from 3.02-3.31%, for the second one from 2.88-3.03%. Improvement in the diet resulted in growth of protein content in the milk of the Anglo-Nubian goats by 0.29%, of the Alpine goats by 0.23% and of the German White goats by 0.15% with regard to the diet K. A similar pattern of changes was observed also for lactose (Fig. 1c). The medians of lactose in milk of animals on the diet K were equal to 4.33-4.56%. The highest index (both for the first and the second diet) was recorded in the Anglo-Nubian goats. When evaluating the influence of

improvement of diet on the lactose content of milk of goats of different breeds we found a statistically significant difference with regard to the diet K for the Anglo-Nubian and German White goats ($p<0.05$). Nevertheless, it was noted that with the diet A the content of lactose in the milk of Alpine goats also featured a tendency to increase. As a whole, improvement in the diet led to growth of lactose content by 0.31, 0.29 and 0.15% for the Anglo-Nubian, Alpine and German White goats, respectively.

Protein and lactose mainly compose dry non-fat milk solids, therefore, the changes in this index (Fig. 1d) are the same as changes of the characteristics considered earlier.

The highest density (Fig. 1e) of the goat milk, both with the diet K and the diet A was recorded in the Anglo-Nubian goats (medians 28.7 and 28.8°A which corresponded to 1028.7 and 1028.8 kg $m^{-3}$). The lowest milk density with the diet K was observed in the Alpine goats (median 27.1°A) and with the diet A it was found in the German White goats (median 27.9°A).

The minimum value of the milk freezing point was found in the Anglo-Nubian goats -0.539°C with the diet K and -0.572°C with the diet A. In the milk of all breeds under study the milk freezing point decreased with improvement of the diet (Fig. 1f).

The somatic cells count in the milk of studied breeds of goats before and after improvement of the diet was rather low: medians from 143-332×$10^{-3}$ cells $mL^{-1}$ (Fig. 2a). According to veterinary requirements of Ukraine, if goat milk contains <500×$10^3$ cells $mL^{-1}$, it is classified as high grade.

The index of conductivity of milk also relates to characteristics indicating an animal's health. After improvement of the diet, the conductivity of the milk of goats of all breeds under study decreased (Fig. 2b). This is an indicator of improvement of the animal's health, since, milk conductivity increases with the development of mastitis in lactating females.

With regard to pH of the milk, after improvement of the diet in the Anglo-Nubian goats this index featured the tendency to decrease while in the German White and Alpine goats it did not change (Fig. 2c). Titratable activity varied inversely with regard to pH index (Fig. 2d): with improvement of the diet titratable activity of the milk of the Anglo-Nubian goats had the tendency to increase, while in the German White and Alpine goats it remained unchanged.

With poor feeding (the diet K) the morning milk yields per one goat were equal for different breeds to approximately 300 mL (Fig. 2e). After improvement of feeding conditions (the diet A) the milk yield in Alpine goats almost tripled: medians were equal accordingly to 302 and 884 ml. Milk yield in the German White goats also increased more than 2.5 times: the median for the diet K was equal to 284, for the diet A to 817 mL. The insignificant increase in the morning milk yield in the Anglo-Nubian goats is connected, in our opinion with approaching end of lactation (the scheduled birth of their kidding at the farm is two months earlier than with the other goats). In any case, improved feeding resulted in the increase of milk yield in goats of all three breeds under study.

The mean change in milk characteristics for each individual goat regardless of its breed under the influence of diet improvement (Fig. 3) was the most considerable for fat (204%) and milk yield (223%). For the other characteristics analyzed, the median of the specific animal for the diet A amounted to 96-109% of the values of the characteristic in the conditions of the diet K (Fig. 3).

Cluster analysis of the studied characteristics showed a maximum similarity in variability for the characteristics of dry non-fat milk solids, lactose and total protein (Fig. 4). A lesser degree of correlation with these three characteristics is displayed by milk density. Fat and milk yield show an even smaller degree of coupling with the characteristics mentioned above. The second group, the changes of which changes are practically not dependent on all characteristics mentioned above, comprises freezing point, conductivity, somatic cells count and pH (Fig. 4). Acidity of the goat milk has the least degree of coupling with all characteristics studied.

Regardless of the fact that usually in summer period fat content in goat milk is rather high, according to the results of our studies in summer the fat content in milk of the goats on the lean diet was equal to max. 2.62% (the highest median). With regard to protein, its content only in the Anglo-Nubian goats was equal to little more than 3% in the summer period. Maurer, etc., recorded protein in milk of Saanen and Alpine goats from 27.0-29.2 g $kg^{-1}$ (on average 2.8%) and fatness equal to 30.2-34.1 g $kg^{-1}$ (on average 3.2%). According to the data from Yangilar (2013), the average protein content in milk of the British breed Saanen is 2.6%, Nubian in Great Britain-3.6%, Alpine and Saanen in France-3.2% and fat content of 3.5, 4.9 and 3.6%, respectively. In our studies, a significant increase of fat and protein content in milk was recorded after improvement in the diet.

In the opinion of Fulton, the freezing point of normal goat milk should be <-0.534°C. According to results of the studies of Maurer, etc., the freezing point of the goat milk is <-0.540°C. In our study, we present the figures which are higher than those of other authors, especially for milk of the German White goats. Besides, an inverse relationship between protein content and freezing point was found: with increase of protein content in the goat milk freezing point was reduced.

According to the data from Yangilar (2013), the average content of lactose in milk of goats of the British breed Saanen is 4.3% and of Nubian goats in Great

Britain-4.5%. In our studies average values of lactose in milk of the German White goats (close to the Saanen breed) during the experiment varied from 4.4-4.5% and of the Anglo-Nubian goats from 4.5-4.8%. When the diet was improved, an increase in lactose content in the goat milk was recorded as well.

One of the main factors of safety for consumption of animal milk is the somatic cells count indicating the absence of mastitis in goats. Many scientists pay considerable attention to this (Jimenez-Granado *et al*., 2014; Shapovalov *et al*., 2015). In the opinion of Maurer, etc., variations in the somatic cells count in milk of cows and sheep are very similar but for the goats these variations need to be interpreted differently. Somatic cells in goat milk comprise both defense cells and epithelial cells. Therefore, the somatic cells count in goats is much higher than in cows and sheep. With age, at the end of lactation and under influence of other factors this characteristic increases even without involvement of infection agents. Goat milk should contain minimum $1000\times10^3$ cells $mL^{-1}$.

Jimenez-Granado *et al*. (2014) evaluated the effect of various factors on the somatic cells count in goat milk including that under influence of changes in diet. Fedele *et al*. (1996) when studying the effects of various diets on the somatic cells count, note that when goat feeding is based only on pasturing, the somatic cells count is somewhat lower than when barley is added to the diet; this index significantly increases upon addition of protein concentrate. A similar study was carried out by Sanchez-Rodriguez, etc., comparing various types of diet: complete diet, semi-complete diet, mix of grain crops or mixed feed. Herds of animals on a balanced diet have shown a somatic cells count much lower than on other diets. According to the data from De Souza *et al*. (2009), the average somatic cells count in milk of goats which were milked by hand was equal to $1\ 121\times10^3$ cells $mL^{-1}$ while with the use of machine milking it was less ($848\times10^3$ cells $mL^{-1}$). In our studies when machine milking was used average values of somatic cells count were much lower compared with those in the experiments of other authors to $380\times10^3$ cells $mL^{-1}$.

Upon addition to the basic diet (alfalfa hay or 8 mixed vegetative forages: wheat-*Triticum aestivum* L., berseem clover *Trifolium alexandrinum* L., wheat/ryegrass *Lolium multi orum* Lam., Sudangrass *Sorghum bicolor* (L.) Moench and crabgrass *Digitaria ciliaris* (Retz.) Koeler) of concentrate, the percentage of milk fat, amount of protein in milk and daily milk yield statistically increased (Min *et al*., 2005). The data from Kawas *et al*. (1991) showed that with the use of forage-to-concentrate ratios of 75:25 fat indices were significantly higher than in case of goats fed at forage-to-concentrate ratios of 45:55; no significance of the effect of the concentrates on milk production was determined.

Our research found that introduction into the diet of granulated alfalfa hay and increase of the amount of concentrated feed from 300-400 g per head resulted in an increase in milk yields and fat content in milk (with a statistically significant difference found) in goats of all breeds under study. However, according to other researchers, the amount of concentrated feed in the diet should be moderate. Results of many authors (Beauchemin and Buchanan-Smith, 1989; Ollier *et al*., 2009) show that an increased amount of concentrates in the diet of cows and goats reduced the milk yields.

## CONCLUSION

Since, the fat content in milk is an indicator for which the farmer receives additional payment, scientists are studying various methods of improving it. Besides, by introducing additives to the diet, ways to reduce the saturated fatty acids and to increase specific unsaturated fatty acids in milk of ruminants are developed. Considerable increase of fat in milk is achieved if sun ower-seed oil, linseed oil supplements or whole intact rapeseeds are added to a diet based on grass hay or maize silage (Bernard *et al*., 2009; Ollier *et al*., 2009). In this case, the amount of milk decreases. The milk fat index is lower when formaldehyde-treated linseed is used as an additive, compared with oleic sun ower oil -2.13 and 2.32 kg $g^{-1}$ accordingly (Bernard *et al*., 2005). Feeding with lipids influences the milk fat concentration in lactating goats and cows, but does not change the amount of milk obtained considerably (Palmquist and Moser, 1981; Sampelayo *et al*., 2007; Hervas *et al*., 2008). The nutritional value of milk fat in sheep grows due to increase in potentially healthy fatty acids owing to addition of 6% sunflower oil (rich in linoleic acid) (Hervas *et al*., 2008). Addition of olive cake silage to the diet of sheep and goat increases the content of linoleic and oleic acid in milk fat (Vasta *et al*., 2008).

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