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AGE VARIABILITY OF MAMMARY GLAND HISTOSTRUCTURE IN DAIRY AND NON-DAIRY ANIMALS OF DIFFERENT BREEDS AND ORIGIN

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Abstract

Increase in milk production and improvement of milk quality must be addressed, along with of paratypic factors, through further researches of breast morphology and physiology. These studies are targeted not only at its morphological and functional characterization, but also at establishing basis for changing the body's activities and improvement of dairy animals. For most dairy breeds in the process of breeding almost reached the biological threshold of productivity. In addition, with the development of highly mechanized and automated technologies for milk production, the requirements for the selection of animals for adaptation to such conditions, in particular for the state of the udder, have increased. Therefore, an additional reserve can be the improvement of dairy cattle and improve the quality of milk on the basis of in-depth studies of the morphological, functional characteristics and physiology of the breast. The most informative data are presented on the structure and function of the udder in species with high initial milk yield and high quality indicators in comparison to the most common breeds of cattle. In the scientific literature there are no comparative data on histological mammary gland of cows and female-yaks. The results presented by us in this study fill this gap. Investigations of histostructure of udder in cows were carried out on black-motley and Brown Swiss breeds and their crosses with Holsteins (F_1 and F_2, Lenin APS Farm), and on the local population of Brown Swiss cows and female-yaks imported from Tuva and Kyrgyzstan (LLS "Elbrus Agroinvest" farm). The microstructure was investigated using 2×3 cm^2 specimens taken between dairy base and the base of the tank throughout the udder fraction along a line passing through the center of the teat canal and lactic sinus in the right front of teat. In the mammary gland of $^1/_2$ Holstein-Swiss crossbred cows the diameter of alveoli were the largest and reached 119 μm in the cows of the third lactation, which is 6,2-3,7 % higher compared to peers of other groups ($P > 0.999$). The smallest diameter of the fat cells are in the black-motley cows (68.3 μm) and the largest ones were in Holstein-Swiss crossbred hybrids of the third lactation, the rest of cows take an intermediate position. The greatest increase in the diameter of the fat cells with age was in Holstein × black-motley hybrids F_2 in which the figure ranges from 68.6 μm in heifers to 77.3 μm in cows of the third calving. Consequently, according to the development and size of structure elements most important for milk production (the size of the alveoli, and the diameter of the fat globules), the animals improved by Holsteins are superior to the peers of pure Brown Swiss and black-motley cows. It was established that in local Brown Swiss cows the alveoli diameter is higher than that of female-yaks, regardless of their origin, and averages 9.1-11.3 μm. By the fat cell diameter, the female-yaks were superior to the Brown Swiss peers by 4.5-5.4 μm on average. Thus, mammary glands of Brown Swiss cows and female-yaks imported from Tuva and Kyrgyzstan have characteristics features, namely Brown Swiss cows of local population have larger quantity of glandular epithelial cells, the diameter of alveoli, and the thickness of the main strands, whereas female-yaks have a higher concentration of adipose tissue, a smaller diameter of fat cells and the thickness of interlobular strands. For comparison, we compared the mammary gland in another animal species, the goats of different origin. It was shown that the Zaanen breed has better developed mammary gland with higher biomechanical properties as compared to the local goats' population.

Keywords: cows, yaks, goats, genotype, mammary gland, histological structure, alveoli, adi-

pose cells, connective-woven strands

A deeper understanding of cow mammary gland physiology is a way to increase milk production [1]. In addition, such investigations improve the fundamental understanding of the biology of this organ determining the development of mammals [2, 3]. In Russia, such research was initiated by Liskun who in 1912 described significant differences in the histogram of the udder in dairy (Red Steppe and Yaroslavl breeds) and draft (Gray Steppe) cattle [4].

The shape, size, and condition of the udder determine the resistance to mastitis, milk yield and the productive period longevity [5, 6]. In the Netherlands, for example, the damage from a single case of clinical mastitis ranged from 164 to 235 euros, depending on the month of lactation, and could reach 100 million euros in total [7]. Mammary gland morbidity in the U.S. dairy industry during the year reaches 51%, and the cost of treatment is estimated at an average of $2 billion. The frequency of clinical mastitis in the UK is slightly lower, 32-38%, while in Germany it is up to 60% [8, 9]. The incidence of mastitis in Russian farms ranges from 10-20% to 70-80%. The economic damage caused by this disease to dairy cattle breeding is 150-200 billion rubles per year [10, 11]. A certain relationship between the development of mammary gland pathology in cows and the shape of the nipple and udder was pointed out by Mitev et al. [12] and Asadpour et al. [13]. In recent decades, high milk yielding breeds of dairy cattle have prevailed in livestock, which is accompanied by an increase in the frequency of various pathologies, including mastitis. Counting the number of somatic cells in milk and ultrasonic scanning made it possible to reduce the incidence of mastitis, increase productivity and extend the period of cows' commercial use [14].

Endocrine changes associated with pregnancy stimulate extensive cell proliferation in the mammary gland, which continues in the early stages of lactation. The cell population then decreases markedly until involution is complete [15]. The study of SP (side population) cells of the mammary gland revealed that they represented an undifferentiated subfraction of epithelial cells. SP cells retain the potential for differentiation in vitro into clones typical of the mammary gland and normal lobular and duct structures in vivo. Mammary gland stem cells [16, 17] were studied and identified with their preliminary labeling and mammary gland transplantation for subsequent localization analysis [18].

The mammary gland is one of the most labile and easily changing organs in animals. The reasons for these variations are very diverse and depend on the breed [19, 20], age, the month of lactation [19], pregnancy, feeding and housing conditions, cow milking technology [21-24]. The central nervous system, digestive organs, respiratory organs, internal secretion and, to a large extent, blood circulation intensity have a significant influence on the amount of secreted milk [25-27].

To improve the productive and technological qualities of domestic livestock, along with the intra-breed selection, the gene pool of the best foreign breeds is often used for crossing with domestic livestock. Histological studies of the mammary gland in Ayrshire cattle have shown that the daughters of bulls of the Finnish origin have the most developed glandular udder tissue (the number of alveoli per 1 mm^2 was 27.3), while in daughters of bulls of the Canadian origin it was 25.1, with a diameter of 125.1 and 123.5 μm, respectively [28]. Differences between udder quarters in morphology of glandular and connective tissues (different types of duct system branching) were revealed in native Kostroma cows aged 16 months. The best ratio of glandular and connective tissues (38.1% and 61.9%, respectively) was established in quarters with the trunk type of duct system [29].

Similar features are also typical of non-dairy cattle. In young ewes at 6 months of age, the size of the mammary gland tissue anlage was 39.5 μm [30]. In newborn young ewes, glandular tissue is localized in the center of the fatty lobes and has the form of epithelial anlages in the form of islets [31]. In the mammary gland of newborn young ewes, connective tissue prevails over glandular tissue (the average ratio is 0.7:1.0). Adult sheep show a similar trend, with the portion of connective tissue in the mammary gland increasing to 65% vs. to a 35% increases in glandular tissue. During pregnancy, the development of glandular tissue in the mammary gland of ewes intensifies.

In the mammary gland of the Saanen goats the adipose tissue surrounded by the bands of stromal connective tissue prevails during the neonatal period. Parenchyma is comprised of lobules separated by zones of connective tissue. Adipose tissue with a small amount of glandular tissue in the form of epithelial anlages is localized directly in the lobule. One-year-old Saanen goats have 33.5% of adipose tissue, 41.5% of glandular tissue and 25.0% of connective tissue. Goats are thought to have a fully developed mammary gland at this age [32].

We have not found any reports on the morphology and histological structure of the mammary gland in female yaks.

Diseases caused by metabolic disorders and reduced resistance to environmental factors are known to occur when the genetic potential of animals is fully realized [33, 34]. In addition, modern machinery and automated technologies in dairy farming necessitate breeding animals for adaptation to such conditions, in particular, for udder health [35, 36].

In the Kabardino-Balkarian Republic, the improvement of Brown Swiss and Black-and-White cattle is carried out with the use of Holstein livestock gene pool of Black-and-White cattle. However, there is no data on the effect of crossbreeding with Holstein cows on the structure and function of the mammary gland. There is also no information on the histological structure and biomechanical properties of the mammary gland of female yak and goats, the breeding of which is expedient seeing the environmental and climatic factors of the region.

In this paper we present for the first time comparative data on the mammary gland histogram of Brown Swiss cows, their crossbreeds with Holstein cows (different generations), as well as the yaks imported from Tuva and Kyrgyzstan, and goats bred in the Republic. The results obtained complement the existing understanding of the structural and functional organization of this mammalian organ.

The aim of the work was histological investigation of the peculiarities of the mammary gland structure in animals of different species and breeds depending on the origin and type of use.

Techniques. The investigations were conducted from 2012 to 2017.

In Lenin Agricultural Production Cooperative (Urvansky District, Kabardino-Balkarian Republic), six groups of cows were formed, $n = 5$ each. Group I comprised Swiss animals, Group II crossbreed cows (Holstein × Swiss) F_1, Group III their peers F_2, Group IV Black-and-White cows, Group V half-bred cows (Holstein × Black-and-White cattle) F_1, Group VI their peers (blood $^1/_4$ Black-and-White cattle + $^3/_4$ Holstein) F_2. In Elbrus Agroinvest LLC (Bezengi village, Chereksky District, Kabardino-Balkarian Republic) female yaks of populations imported from Tuva and Kyrgyzstan and Brown Swiss cows of the local population (5 animals per each group) were selected. Saanen goats (3 ewes) were from the Sarsky farm (Maysky District, Kabardino-Balkarian Republic), and local goats (3 ewes) from private farms (Arik village, Tersky District, Kabardino-Balkarian Republic). All farms were free from infectious and invasive diseases.

For histological examination, 2×3 cm tissue samples were taken between the base of the milk tank and the entire base of the udder quarter along the line through the middle of the teat canal and the breast sinus of the right front teat. The samples were preserved in a 10% formalin solution for 24 hours and put to 5% solution for permanent storage. The 5-10 μm-thick sections were prepared on a sled section cutter MPS-2 (Russia), 10-15-μm-thick sections on a freezing section cutter MZ-2 (Russia). Preparations were stained with hematoxylin and eosin to examine the overall histological structure (a microscope MBS-10, LZOS JSC, Russia, magnification of ×4, ×10, ×40, ×100 for and ×10 for eyepiece). The quantitative tissue ratio (glandular, adipose and connective) was determined by the triangle method. With the help of a drawing machine, the diameter of milk alveoli and the thickness of connective-tissue bands were measured, and the number of glandular epithelium cells was calculated per 1 mm^2. To assess structures, the tissue samples were embedded into paraffin using the standard method; paraffin sections were prepared on a MPS-2 section cutter. The histological study was carried out at the Kabardino-Balkarian Pathological Anatomical Bureau of the Ministry of Health of the KBR. A total sample comprise 5 histological sections from each group of cows and female yaks from Lenin Agricultural Production Cooperative and Elbrus Agroinvest LLC, 3 histological sections from Saanen goats from Sarsky farm and 3 histological sections from local goats from Arik village.

Biomechanical properties (elasticity, flexibility, and strength) were assessed in udder tissue sampled from the central part of the suspensory ligament. To test 6 samples from two groups of goats, i.e. the local and Saanen populations, a universal bursting machine REM-50-A (Metrotest LLC, Russia) was used.

Biometric data processing was performed as per the description [37]. The arithmetic mean (*M*), standard errors of the mean (±SEM), and the reliability of differences between mean values were estimated by Student's *t*-test at three confidence levels (P > 0.95; P > 0.99 and P > 0.999).

Results. The monitoring of the mammary gland microstructure in the examined animals showed a different ratio of tissue types depending on the breed (genotype) of individuals (Table 1).

1. Udder tissue ratio in the 2nd calving cows depending on the origin (*M*±SEM, Lenin Agricultural Production Cooperative, Urvansky District, Kabardino-Balkarian Republic, 2012-2015)

Group (*n* = 5)	Tissue		
	glandular	connective	fatty
I	66.7±1.20	23.2±1.13	10.1±0.67
II	71.2±0.93*	19.2±1.21*	9.6±0.80
III	74.6±1.10**	16.7±1.68*	8.7±1.04
IV	68.4±1.32	21.9±0.98	9.7±0.59
V	73.6±0.85*	17.2±1.75*	9.2±0.73
VI	76.7±1.04**	15.3±1.87*	8.0±0.92

N o t e. I — Swiss; II — Holstein × Swiss, F_1; III — Holstein × Swiss, F_2; IV — Black-and-White; V — Holstein × Black-and-White, F_1; VI — Holstein × Black-and-White, F_2.
*, ** Differences are statistically significant at P > 0.95 and P > 0.99, respectively (for Group II and Group III as compared to Group I, for Group V and Group VI as compared to Group IV).

The greater share of glandular tissue was found in the F_2 Holstein and Black-and-White crossbreeds with the advantage of 3.1% (P > 0.95) over peers in F_1 and 8.3% (P > 0.99) over purebred Black-and-White cows. When comparing the Swiss and Holstein-Swiss cattle, the amount of glandular tissue was higher in crossbreeds (by 4.5-7.9%, P > 0.95-0.99). In F_2 cows, the share of connective and fatty tissues decreased due to the increase in the amount of glandular tissue. Thus, the amount of connective tissue in the Swiss cows was 4.0-6.5% higher (P > 0.95) than that of the crossbreed Holstein-Swiss peers in

F_1 and F_2, and the fat tissue was 0.5-1.4% higher. The differences between Black-and-White cows and Holstein and Black-and-White crossbreeds in distribution of these tissues were similar. In the Swiss cows, a higher proportion of fatty tissue in the udder is likely to be associated with a better predisposition to milk fat synthesis.

The histological data we obtained indicate distinctive features in the structure of the mammary gland of the Black-and-White and Brown Swiss cows, as well as their crossbreeds with Holstein cattle at all ages (Table 2).

2. Histostructure of the mammary gland depending of breed and age of cows (*M*±SEM, Lenin Agricultural Production Cooperative, Urvansky District, Kabardino-Balkarian Republic, 2012-2015)

Group (*n* = 5)	Calving	Diameter, μm		Thickness of connective-tissue bands, μm			Number of epithelial cells per 1 mm²
		alveoli	adipocytes	main	interlobular	intralobular	
I	1st	73.5±1.32	70.4±0.68	471.3±6.09	84.3±1.47	30.3±1.08	3.56±0.11
	2nd	80.0±0.41	72.6±2.10	480.3±4.26	88.6±1.77	31.0±1.41	3.76±0.10
	3rd	89.0±1.41	78.3±1.47	492.3±6.17	91.0±0.41	34.0±0.70	4.06±0.14
II	1st	90.3±1.77***	72.3±1.47	530.0±6.28***	70.6±1.77**	29.0±1.41	3.80±0.14
	2nd	97.3±1.78***	78.0±2.54	534.3±5.75***	74.0±1.41***	31.0±0.41	3.93±0.08
	3rd	112.0±2.54***	80.6±1.78	550.0±6.36***	77.3±1.47***	33.0±0.07	4.03±0.14
III	1st	101.3±4.60***	74.3±2.85	539.0±8.33***	68.0±4.24***	29.3±2.48	3.90±0.21
	2nd	116.0±4.24***	76.0±3.94	555.3±11.66***	70.0±3.24***	30.7±2.48	4.10±0.20
	3rd	119.0±4.95***	80.4±6.30	570.0±8.86***	77.0±4.41**	34.3±2.58	4.23±0.20
IV	1st	74.0±1.41	68.3±1.47	467.0±4.30	79.0±1.41	32.0±0.71	3.50±0.12
	2nd	79.0±1.40	70.0±1.22	480.0±3.53	80.3±1.47	33.0±0.70	3.60±0.12
	3rd	90.0±1.87	73.0±1.41	491.0±1.13	88.0±0.41	35.0±0.70	3.80±0.13
V	1st	90.3±2.16***	68.6±1.77	495.0±6.81**	70.0±1.87**	31.0±1.41	3.66±0.10
	2nd	99.6±2.48***	73.3±2.16	502.0±7.64*	72.0±2.12*	31.3±1.47	3.80±0.12
	3rd	110.6±2.48***	77.3±2.16	515.0±5.33**	76.3±1.77***	34.0±1.41	4.00±0.12
VI	1st	111.0±3.53***	70.3±2.48	520.0±7.07***	65.0±2.12***	30.0±1.87	3.90±0.14
	2nd	115.0±3.93***	75.0±2.82	540.0±7.87***	69.0±2.82**	32.0±2.12	3.90±0.18
	3rd	118.0±3.24***	77.3±2.16	556.0±8.83***	75.0±2.54**	33.0±1.41	4.10±0.14

N o t e. For a description of the groups, see Technique section.
*, **, *** Differences are statistically significant at P > 0,95; P > 0,99 and P > 0,999, respectively (for Group II and Group III as compared to Group I, for Group V and Group VI as compared to Group IV).

Regardless of the breed and genotype of cows, all analyzed parameters increased with age. Other things being equal, they were higher in crossbreds with Holstein cattle. A larger diameter of alveoli was characteristic of the F_2 Holstein crossbreeds with Swiss and Black-and-White cattle, at a difference of 27.8 μm (P > 0.999) and 37.0 μm (P > 0.999), respectively, for individuals of the 1st calving, of 36.0 μm each (P > 0.999) for the 2nd calving, and 30.0 μm (P > 0.999) and 28.0 μm (P > 0.999), respectively, for the 3rd calving. Crossbreeds F_1, regardless of the parent breed, occupied an intermediate position relative to the extreme values. In F_2 (Swiss × Holstein) of the 3rd calving the diameters of alveoli were largest, being 119 μm on average which is 6.2-3.7% higher than the same indicator in female peers from Groups I, II, IV, and V (P > 0.999). Differences in this indicator between F_2 animals of Groups III and VI (0.8%) were unreliable. It should be noted that the maximum increase in the alveoli diameter from the 1st to the 3rd calving was characteristic of half-bred crossbreeds of Holstein × Swiss (+21.7 μm, P > 0.999) and Holstein × Black-and-White cattle (+20.3 μm, P > 0.999).

The smallest diameter of fat cells in the 1st lactation was characteristic of Black-and-White cows (68.3 μm), while the largest one was in $^1/_2$- and $^3/_4$-bred crossbreeds Holstein × Swiss (F_1 and F_2) (72.3 and 74.3 μm, respectively); all other groups occupied an intermediate position. The tendencies were similar at the age of the 2nd and 3rd lactations. A greater age-related increase in the diameter of fat cells was characteristic of the crossbreeds Holstein × Black-and-White cattle in F_2 with a variation from 70.3 μm in first calves to 77.3 μm in animals of the 3rd calving.

These data on the differences in the mammary gland histogram between domestic breeds and their crossbreeds with the improved dairy cattle breeds are consistent with the results of earlier reports [20, 24].

Alveoli and excretory ducts are surrounded by connective tissue. Penetrating between the lobes, lobules, and alveoli, connective tissue forms a mesh network consisting of bands and interlayers [1]. The data we obtained lead to the conclusion that with age the thickness of connective tissue bands increases in all groups of dairy cattle. To the greatest extent it was characteristic of the main bands, in the least — of intralobular bands. When comparing the indices of Black-and-White cows and crossbreeds of Holstein with Black-and-White cattle, it turned out that thicker main bands (regardless of the number of lactation) are characteristic of cows in F_2, whose superiority over purebred peers was 53 μm ($P > 0.999$), 60 μm ($P > 0.999$), and 65 μm ($P > 0.999$). In crossbred Holstein and Swiss (F_2) cows, these bands were thicker in the 3rd lactation (2.5-16.0% higher than the other groups).

A slightly different trend was observed in the thickness of the interlobular bands: they have increased with age, and the increase in the Holstein thorough-bredness has led to a decrease in this figure. For example, in F_1 and F_2, the thickness of interlobular bands increased from 68.0 to 77.3 μm for the Holstein × Brown Swiss cows, and from 65.0 to 76.3 μm for the Holstein × Black-and-White cows. It should be noted that regardless of lactation, the thickness of the interlobular connective tissue bands was higher in purebred Brown Swiss and Black-and-White individuals. The corresponding superiority of Swiss cows over Holstein-Swiss cows was 13.7-16.3 μm ($P > 0.99$-0.999) for the 1st calving, 14.6-18.6 μm ($P > 0.999$) for the 2nd calving, and 13.7-14.0 μm ($P > 0.99$-0.999) for the 3rd calving. Similar differences occurred between groups of Black-and-White and crossbreed Holstein-Black-and-White cattle with the superiority of Black-and-White cows.

The variation in the diameter of the intralobular bands was slightly lower than that of the main and interlobular ones: in cows of all studied genotypes, irrespective of the lactation, this index ranged within 29.0-35.0 μm and changed insignificantly with higher Holstein thorough-bredness.

The number of epithelial cells per 1 mm^2 of the alveoli area was the smallest in the Black-and-White first calving heifers, and the largest in F_2 animals, regardless of the used mother breed. Thus, the differences in this indicator were 0.24-0.34 cells per mm^2 between Swiss and Holstein-Swiss first calving heifers, in favor of crossbreeds, and 0.16-0.4 cells per mm^2 between Black-and-White and Holstein-Black-and-White cows. The superiority of crossbreeds (of different genotype) over purebred peers in the number of epithelial cells per 1 mm^2 area of the alveoli was also noted in the 2nd and 3rd calving.

Thus, the study of mammary gland tissue specimens of cows obtained from crossing of Brown Swiss and Black-and-White breeds with bulls of the Holstein breed of black-and-white color indicates that the development of structural elements of the mammary gland, which are the most important for milk secretion, in improved animals and original breeds differs. The size of the milk alveoli and the diameter of the fat globules in the crossbreeds were larger than those of the Brown Swiss and Black-and-White peers, and these figures, with an increase in the Holstein breed, increased with a slight age-related decrease in the thickness of the interlobular bands.

A comparison of the mammary gland tissue types of the Swiss cows of the local population and the yak females imported from Tuva and Kyrgyzstan showed (Table 3) that the share of connective tissue in yaks of different populations was almost the same, the 30.8-30.9% which was 5.7-5.8% higher than in the peers of the Brown Swiss breed (P > 0.999). However, the yaks imported to the region were inferior to the local population as to the relative amount of glandular tissue (this indicator is usually used to judge the milk yielding). Differences in the glandular tissue fraction between Swiss cows and yaks varied in the range of 7.5-9.7% (P > 0.999). As to fatty tissue proportion in the mammary gland, yaks from Kyrgyzstan were superior with a 2.1% excess (P > 0.999) compared to peers from Tuva and 3.9% excess (P > 0.999) compared to Brown Swiss cows of the local population, which explains the higher fat concentration in yak milk.

3. Tissues ratio (%) in the mammary gland in the local population of Brown Swiss cows and female yaks imported from Tuva and Kyrgyzstan (*n* = 5 in each group, *M*±SEM, Elbrus Agroinvest LLC, Bezengi village, Chereksky District, Kabardino-Balkarian Republic, 2015-2016)

Tissue	Local Brown Swiss cows	Imported yak females	
		from Tuva	from Kyrgyzstan
Glandular	64.3±1.30	56.8±0.90*	54.6±0.70*
Connective	25.1±0.50	30.8±0.60*	30.9±0.60*
Fatty	10.6±0.20	12.4±0.10*	14.5±0.20*

N o t e. Animals of the 3rd calving were examined.
* Differences with indicators in Brown Swiss cows are statistically significant at P > 0.999.

A comparison of the udder histogram at the age of the 3rd calving in the Swiss cows of the local population and female yaks showed (Table 4) that the alveolar diameter in the local Swiss cows is larger than in the yaks, regardless of the origin of the latter, with the average excess by 9.1-11.3 μm, P > 0.999, which indicates insignificant differences in this parameter between yaks of different origins and the advantage of double use cows. The diameter of fat cells in yaks was 4.5-5.4 μm (P > 0.99) larger than in Swiss peers. More developed fat cells of the mammary gland contribute to higher milk quality in yaks.

4. Histostructure of the mammary gland in local Brown Swiss cows and female yaks imported from Tuva and Kyrgyzstan (*n* = 5 in each group, *M*±SEM, Elbrus Agroinvest LLC, Bezengi village, Chereksky District, Kabardino-Balkarian Republic, 2015-2016)

Indicator	Local Brown Swiss cows	Imported yak females	
		from Tuva	from Kyrgyzstan
Diameter, μm:			
alveoli	90.6±1.45	79.3±1.22***	81.5±1.06***
adipocytes	77.1±0.88	82.5±1.03**	81.6±0.90**
Thickness of bands, μm:			
main	501.4±5.13	472.5±3.96***	476.3±4.78**
interlobular	75.4±1.98	93.0±2.46***	90.4±2.31**
intralobular	33.4±1.36	34.5±1.45	34.1±1.60
Number of epithelial cells per 1 mm^2 alveoli surface	4.20±0.08	3.84±0.06**	3.91±0.07*

N o t e. Animals of the 3rd calving were examined.
*, **, *** Differences with indicators in Brown Swiss cows are statistically significant at P > 0.95; P > 0.99 and P > 0,999, respectively.

The thickness of the connective tissue bands varied depending on the origin of the animals. Analysis of connective tissue parameters in yak females imported from Tuva and Kyrgyzstan indicates the absence of significant differences. At the same time, the thickness of the main bands was higher in the local Swiss population, by 25.1-28.9 μm on average, of interlobular bands — in yaks, by 15.0-17.6 μm on average (P > 0.99-0.999). We did not find any significant differences in the thickness of intralobular bands between animals of different origins in these groups. The number of glandular epithelium cells per 1 mm^2 alveoli area was higher in the Brown Swiss cows of the local population than in yaks of different origins, by an average of 0.29-0.36 cells per mm^2 (P > 0.95-0.99).

As in dairy cattle [20, 24, 28], the productive qualities of dairy goats [27, 32, 38] in many respects are due to the development (histogenesis) of a mammary gland and the prevalence of different tissues. So we compared histogram and biomechanical parameters of mammary gland tissue in goats of different origins (Table 5).

5. Tissues ratio, histogram and biomechanical properties of the mammary gland in goats of different origins (n = 3 in each group, M±SEM, Kabardino-Balkarian Republic, 2016-2017)

Indicator	Breed, origin		Saanen goats compared to the local goats
	Saanen	local population	
Tissue ratio, %:			
glandular	65.3±1.70	48.6±1.50	+16.7***
connecting	20.6±0.40	18.7±0.50	+1.9*
fatty	14.1±0.30	32.7±0.90	–18.6***
Diameter, microns:			
alveoli	94.5±1.50	78.6±1.30	+15.9**
adipocytes	78.0±1.50	75.3±1.20	+2.7
Thickness of bands in the connective tissue stroma:			
main	63.4±1.00	49.5±0.80	+13.9***
interlobular	42.6±0.70	36.0±0.50	+6.6**
intralobular	18.3±0.30	17.4±0.30	+0.9
Biomechanical properties of glandular tissues:			
tensile strength, MPa	10.3±0.20	8.9±0.10	+1.4**
flexibility, MPa	5113±36.70	4562±28.40	+551***
elasticity, %	19.3±0.40	17.4±0.30	+1.9*

N o t e. Saanen goats were from Sarsky farm (Maysky District), local population goats — from Arik village (Tersky District), animals were examined in the 3rd lactation.

*, **, *** Differences with goats of the local population are statistically significant at P > 0.95; P > 0.99 and P > 0.999, respectively.

The analysis of goat mammary gland tissue specimens revealed a different ratio of tissue types. For example, Saanen goats had the largest volume of glandular tissue, 65.3% which was 16.7% higher than that of local goats (P > 0.999). Differences in the connective tissue content between goat groups varied by 1.9% (P > 0.95), with the best ratio of parenchyma and stroma, 1.88:1, in the mammary gland of the Saanen goats as compared to local goat population with 0.94:1. At the same time, fat tissue was less developed in the mammary gland of Saanen goats (by 18.6% on average, P > 0.999). Large diameters of alveoli (by 15.9 μm, P > 0.99) were characteristic of Saanen goats, while no significant intergroup differences in the area of fat cells were found. There were differences in the thickness of connective tissue bands of different origins, especially between the main and interlobular bands, with an excess of 13.9 μm (P > 0.999) and 6.6 μm (P > 0.99), respectively, in the Saanen animals.

The maximum values of strength, flexibility, and elasticity of mammary gland tissues in the central region of the suspensory ligament were characteristic of Saanen goats. Thus, their advantage was 1.4 MPa (P > 0.99) in terms of strength, 551 MPa (P > 0.999) in terms of elastic modulus, and 1.9% in terms of maximum elastic deformation (P > 0.95). The higher biomechanical properties of the mammary gland in Saanen goats compared to local individuals are likely to be due to the selection of breeds for both milk productivity and udder morphology.

Thus, the results of the analysis of the histological structure and properties of the mammary gland of cattle, yaks, and goats allow drawing the following conclusions. Animals improved by holsteinization exceed the peers of the Brown Swiss and Black-and-White breeds both in proportion of glandular tissue in the mammary gland and in the development and size of structural elements the most important for the milk secretion (milk alveoli, fat globules). A comparison of the mammary gland of the Brown Swiss cattle and yaks imported from Tuva and Kyrgyzstan revealed the following peculiarities. In Swiss cows of local population, there are more glandular epithelial cells, a larger alveoli diameter and thickness of main bands. In yak females of different populations, fatty tissue proportion and the thickness of interlobular bands are increased and the diameter of fat cells is decreased. Among goats of different origins, a more developed mammary gland with high biomechanical properties is characteristic of the Saanen breed. Regardless of species, more yielding dairy animals differed from the less productive livestock by the predominance of glandular tissue, epithelial cells, thicker main bands and improved biomechanical properties of the mammary gland tissues.

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