Review

Landmark native breed of the Orenburg goats: progress in its breeding and genetics and future prospects

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Abstract

This paper reviews information about a unique and iconic breed of the Orenburg Oblast, the homeland and the only place where the best herds of Orenburg down-hair goats in Russia are concentrated. Three types of these small ruminant animals are widespread on the territory of the region: Orenburg purebred gray goats, Orenburg purebred white goats, as well as crossbred white goats of F_1 White Don × White Orenburg. Currently, at the farms of the Orenburg region, animals are selected according to their phenotype, with selected traits being color, weight and length of down hair. In recent years, the Orenburg goat breed has become an object of genetic research using various marker systems including immunogenetic, microsatellite, mtDNA and SNP markers. Overall, these studies evidence about the uniqueness of the allele pool in the landmark native breed of the Orenburg goats, which is a complex dynamic genetic system, prioritizing its further in-depth genome research and breeding applications.

Keywords: Orenburg goats; history; breeding; selection; genetics

1. Introduction

The Orenburg Oblast (Figure 1) is homeland to and the only place where the best herds of Orenburg down-hair goats in Russia are concentrated in terms of their performance traits are concentrated in Russia [1]. Figures 1 and 2 show that goats of this old native breed have distinctive economically important traits: a fairly high down hair (cashmere) productivity, fine down-hair fabric of the most valuable quality, a relatively large live weight, high fertility, and the ability to acclimatize well to harsh natural and climatic environments [2]. As such, the Orenburg breed is considered as *a valuable national breed* of goats [3].

Contemporary animal husbandry is characterized by a tendency toward a loss of the genetic resources of farm animals due to the rapid global spread of a small number of the most highly productive breeds, and displacement of less productive aboriginal breeds well adapted to certain local economic and climatic conditions [4–8]. The indigenous breeds, like the Orenburg one, have a limited gene pool, so their loss is irreparable. For this reason, there is an arising demand in developing methods for the conservation and improvement of such breeds [9–12].

Figure 1. Location of the Orenburg Oblast (red area) in Russia. Bottom inserts (author's photos): male (left) and female (right). The map was prepared by TUBS (own work). This W3C-unspecified vector image was created with Adobe Illustrator; the file was uploaded with Commonist; and the vector image includes elements that have been taken or adapted from this file: Russia edcp location map.svg (by Uwe Dedering), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=15939024.

Figure 2. A herd of Orenburg goats at one of the farms of the Orenburg region (author's photo).

At present, the number and range of the Orenburg breed have declined sharply (Figure 3). Given the local breeding of these down-hair goats in the Orenburg Oblast, their qualitative improvement should be carried out using the method of purebred breeding and marker gene selection [13]. Goats of the Orenburg breed are reared in the Republic of Bashkortostan, the Orenburg and Chelyabinsk Oblasts of Russia, as well as in the North Kazakhstan, Aktobe and Ural Regions of Kazakhstan. According to breed surveys, as of January 1, 1985, there were 157 thousand purebred Orenburg goats (Figure 3), including 113.4 thousand head in the Orenburg Oblast and 1 thousand in the Chelyabinsk Oblast [3,14]. By 1997, the number of goats in all categories of farms in the Orenburg Oblast declined to 57.7 thousand, and by 2000 to 32.7 thousand. Afterwards, the number of animals began to grow again. In 2001, the number of Orenburg goats was already 38.6 thousand, 39.4 thousand in 2002, and 43.8 thousand head in 2003. There were 22.6 thousand head at agricultural enterprises, 18.9 thousand head in the population, and 2.3 thousand head at other farms. In 2014, the number of Orenburg goats in agricultural enterprises amounted to 15.4 thousand head [14]. As of the end of 2019, the current population of the Orenburg breed was 6.5 thousand head [15].

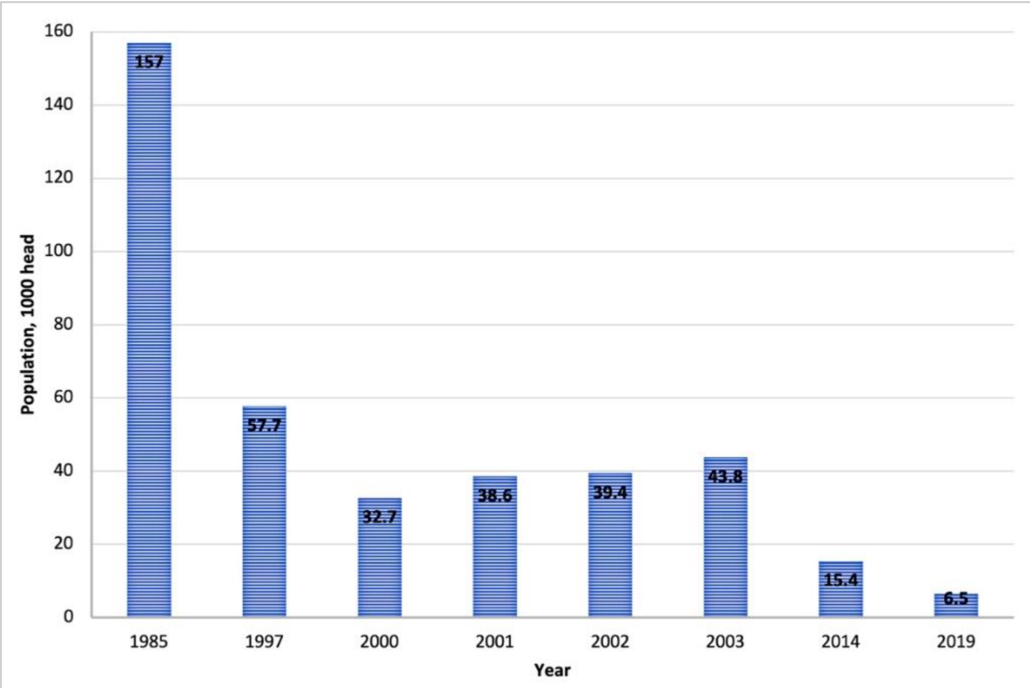

Figure 3. Change in population of Orenburg goats.

2. History of the origin and breeding

The Orenburg breed is one of the main domestic down-hair breeds of goats that has become widely known due to the traditional down-knitting handicraft. The breed was developed in the Southern Urals. The growth of down-hair goat breeding here was closely connected with the old folk home-made down-knitting matier. It originated in the Orenburg region more than 200 years ago, but at first the craftswomen worked on imported raw materials [16]. Gradually, the local Cossack population began to breed Asian goats on their farms. From generation to generation, animals were selected for their down hair performance and ability to tolerate cold winters with strong winds. The whole historical process of creating the Orenburg goat breed can be divided into three stages [17].

The first stage was a long-term selection of native goats by the local people. As a result of many years of breeding, a bulk of animals was created that, in terms of performance and quality of down hair, significantly differed from the original goats of Central Asia and Kazakhstan. As a rule, selective preference was given to large animals with fine dark gray down hair [18]. Little attention was paid to the length of the down hair since it fairly met the requirements. As a result, a stock of large goats appeared that was well adapted to local natural and climatic environments, while being homogeneous in color, with relatively good productivity and high quality down hair. All these economically useful properties later made the Orenburg goats a valuable domestic breed that deserves serious attention. The female had a live weight of 42–43 kg, whereas the yield of down hair was 210–220 g per animal, with its length being 5–5.5 cm and fineness 14–16 µm, and down hair content in wool reached 35–45% [19]. The famous Orenburg downy shawls, “Orenburgskiy pukhovyy platok” in Russian (Figure 4), received medals as unique works of art at the international exhibitions in London (1851, 1862), Paris (1857), Brussels (1958) and Montreal (1967) [3]. This eventually contributed to the creation of the first down knitting factory in the former USSR established in 1930. The first goat-breeding state farm in the Orenburg

Oblast was organized in 1932 in the floodplain of the Guberli River, on the southern spurs of the Ural Mountains. The herd was improved by purebred breeding, when selection was targeted at animals with a fine dark gray coat [16,20,21].

Figure 4. The pattern of the Orenburg downy shawl on a Russian postage stamp (2013).
Issued by the Russian Post and the Publishing and Trade Centre “Marka”; the stamp design by Kh. Betredinova. From a personal collection, Public Domain under the Creative Commons CC0 License, https://commons.wikimedia.org/w/index.php?curid=27218194

The second stage of breeding began in 1937–1938, when, on the initiative of the All-Union Research Institute of Sheep and Goat Breeding (VNIIOK), 279 males and 361 females of the Don breed were brought to the Orenburg Oblast and distributed in 15 districts where developed down-hair goat breeding existed. To obtain high yield of down hair for two and more years of animal use, mass crossings of the Orenburg goats with the Don breed were carried out [1,21]. VNIIOK has been primarily in charge of breeding work with Orenburg goats since 1938 [1], when 32 Don males of one and a half years old were brought to the Guberlinsky State Farm. Of these, 13 sires were assigned to the first category with greater live weight and down hair yield and 19 males were attributed to the second category with lower performance, while an average live weight was 36 kg (in the range of 29 to 43 kg) and yield of down hair 300 to 780 g [16]. For mating, two flocks of goats with a fleece of 150–200 g per individual were selected. Males of an undesirable type obtained from these crossings were culled, and crossbred dams of F_1 and F_2 generations were bred by mating with local individuals. Crossbred animals, especially of F_2 generation, had quite variable performance characteristics. Their yield of down hair ranged between 150 and 800 g, the content of down hair in wool was from 25% to 65%, its length from 4.5 to 13 cm, and fineness from 16 to 23 µm. At the same time, the most valuable qualities of the Orenburg down hair were lost including fineness, elasticity, softness, uniform color, resiliency and strength, although the yield became much higher [14,21]. At the third stage, which began in the 1990s, purposeful selection of goats of the Orenburg breed was carried out for almost 30 years without crossing with other breeds. This phase conforms to the current state in the breed development, with the relevant performance traits (including the yield and structure of the down hair) being provided in more detail in Sections 3 and 5.

Presently, three types of animals (described in more detail in section 5 below) are widespread on the territory of the Orenburg Oblast: Orenburg purebred gray goats, Orenburg purebred white goats, as well as crossbred white goats of F1 White Don × White Orenburg [21]. The leading farms that rear the Orenburg goat breed are the Donskoy Agricultural Production Company (collective farm) in the Belyaevsky District and the Guberlinskoye LLC (goat breeding farm) in the Gaisky District. More than 120 individual farms are engaged in goat breeding, the average number of their herds being 60 head. The largest herds of 200 and more head are located in the Akbulaksky and Yasnensky Districts, and in the city of Novotroitsk [22].

3. Conformation and performance traits

Orenburg goats have a strong build, and some animals have a somewhat rough physique. In size, they surpass most other coarse-haired goats, yielding to the local breeds of Uzbekistan and Kazakhstan [23–25] in height at the withers. The height at the withers of females is 63–66 cm, and that of males 65–75 cm. The live weight of Orenburg goats depends on the season, feeding conditions, age, and other factors. For example, the weight of Orenburg females reaches 44–46 kg in autumn and 36–38 kg in spring, that of males being 70–75 and 55–65 kg, respectively. That is, the live weight of goats in spring is 10–15 kg lower than that in autumn [3,16]. Animals at birth weigh an average of 2.6 kg, at 5 months of age 17.5 kg, at 1.5 years 29.4 kg, at 2.5 years 36.3 kg, at 4.5 years 45.7 kg, and at 6 years old 48.9 kg. At breeding farms, the live weight of elite dams is 46 kg, that of class I dams 42 kg, and that of elite sires 71 kg [14]. In Orenburg breed females, the withers are pointed, slightly protruding above the line of the back. The sacrum is located above the withers and sharply lowered. The head is small, light, and with a slightly concave profile. The limbs are thin and strong. Males have a rough head with a straight or hook-nosed profile and strongly developed horns [26].

The wool of Orenburg goats consists of a coarse guard hair, on average 85 µm thick and 8–10 cm long, and a thin undercoat with a diameter of 14–16 µm and a length of 5–6 cm [3,27]. The thickness and length of the various wool fibers within the breed varies. In young animals, the down hair is thinner, but shorter. Its diameter and length increase with age [27]. In the breed there are goats with both longer and shorter hair. The content of down hair in the wool of Orenburg goats ranges from 31 to 45%, while being from 35 to 37% at breeding farms. Despite the low content of grease, the technological qualities of the down hair are well preserved, since on the skin of animals it is reliably protected from moisture, light and dirt by a longer guard hair. Valuable features of the Orenburg down hair, in addition to fineness, are softness, elasticity, and high uniformity in thickness and length both in the bundle and on different parts of the body (the diameter of the down hair in samples from the shoulder blade and thigh differs by only 0.2–0.3 µm) [1]. Down fibers have an average breaking load ranging from 4.2 to 8.2 g depending on their diameter [3,28]. A serious shortcoming of the down hair in Orenburg goats is a shortened fiber that complicates its processing, reducing the yield of yarn and the quality of products [28]. Down hair performance of Orenburg goats is relatively low. In the best flocks, 300–350 g of down hair is combed from females, and 550–600 g from males [3,26,27]. The output of pure fiber is high, i.e., 98% [29]. The wool shear does not exceed 0.3–0.4 kg. In 2003, the average yield of down hair in the Orenburg Oblast was 286 g per 1 head, with the greatest yield of 326 g being obtained in LLC Budenovsky in the Yasnensky District where crossing with the Don goats was previously conducted. Orenburg goats vary greatly in the amount of fleece, which indicates a high variability of this trait within the breed and makes it possible to select animals based on it [26,27].

The fertility of the Orenburg dams is unstable. According to long-term records, 18-27% of goats give birth to twins. In years with good feeding conditions, the output of kids per 100 dams reaches 130–140, and in unfavorable years it declines to 115–110 or less. However, the potential for multiple pregnancy in goats of this breed is high and increases with age. Twins are born in 10–15% of 2-year-old goats, in 16–20% of 3-year-olds, and in 25–40% of 4-year-olds. Most often, twins and triplets appear in goats under the age of 6–7 years (50–65%). From the age of 7, as a rule, multiple pregnancy decreases, but in some animals it persists up to 8–10 years [3,16]. Orenburg goats have a relatively lower milk production. It varies from 85 to 110 kg with an average milk fat content of 3.9% (in the range of 3.2 to 6.1%). After weaning the kids from each mother, 10–15 kg of milk (up to 40–50 kg) can be produced. Orenburg goats feed well on natural pastures. Slaughter yield is 40–45%. When slaughtering fattened adult wethers, an obtained carcass weight is 25–30 kg. Goats of the Orenburg breed are relatively early maturing, reaching their maximum weight by the age of 4 years, while goats of the Don, Turkmen and Kyrgyz breeds reach it only by 5 years of age [22,27,28].

4. Selection and breeding work

Selection and breeding work is the most effective way to improve the quality of wool and down hair raw materials. Breeding work in down-hair goat breeding should be aimed at increasing the yield of down hair and improving its quality. The size of down hair productivity, other things being equal, is determined by the content of down hair in wool, fineness, length, density, and degree of overgrowth of an animal with down fiber [30].

The content of down hair in wool indirectly affects its quality. If crossbreeding accidentally occurs, offspring goats are characterized by a low down hair content and their down fiber of the second harvest is usually heavily clogged with guard hair, resulting in reduction of its value [7]. Fineness is the most important technological property that enables to make fine and beautiful products from down hair. Selection work in goats of the Orenburg breed, which gives fine down hair, should be focused on preserving this trait in them, and that in goats of the Don breed, its crosses and the Altai Mountain breed, the down hair of which has a larger diameter, be aimed at its thinning [16,26]. However, the selection and pairing of animals of these breeds based on fineness of down hair should not cause its shortening and lowering of down hair performance. The down hair length in goats determines the value of their down hair productivity and, in addition, is an indicator of quality since the longer the down, the more leveled off the yarn made from it is [1]. From long down hair you can get a thinner and longer thread than from the same amount of shorter down. However, with increasing the down hair length, its thickness may also increase because, as a rule, there is a positive correlation between these traits [22]. The density of wool is determined by the number of fibers per skin area unit. When breeding down-hair goats, it is important that the total wool mass grows as a result of an increase in the density of down hair fibers [7].

Breeding work in down-hair goat husbandry should be aimed at eliminating the transitional hair from the coat, since it is necessary to create as large a gap as possible between the periods of molting of down hair and guard hair that depends on the difference in their diameter [31]. Coarse guard hairs seating more deeply and firmly in the skin are less prone to shedding, and if they shed, then at a later time. In addition, in goats, there is a clear inverse correlation between the thickness of the guard hair and down hair. In goats of the finest down-hair breeds, the guard hair is the coarsest [22,28].

The down hair strength in goats of all down-hair breeds is quite high and, to a certain extent, depends on its fineness. When carrying out breeding work, it is necessary to maintain the high strength of the down hair fiber [14].

Color. As a breed with one-color coats, Orenburg goats are most often black (about 90%), other colors being tan, grey or pied [3]. The down hair value depends on its color; monochromatic dark gray and white fluff is more valued [3].

Horns. Down-hair goats should preferably be horned as resulted from observations during the long-term breeding work in Don goats at the Krasnodar State Agricultural University and summarized by Zaporozhtsev [32]. Particularly, it was found that down hair fiber on polled dams and sires turns into dense lumps long before molting. The normal structure of wool in polled animals is broken, the fluff is heavily clogged with guard hair and, as a result, it is difficult to comb it out. The productivity of such animals is reduced, and down hair is often referred to the lower classes. Observations have shown that polled animals, when scratching with their teeth, moisten the wool with saliva, chew it up and slick it down, which is why the fluff gets tangled. Horned individuals, scratching only with horns, do not harm the coat [33].

Thus, the main indicators of the goat wool quality are its color, luster sheen, elasticity, uniformity, and fineness. Goats with hair of an undesirable color that does not have a luster sheen are removed from a herd during grading [34]. When selecting goats for fineness and uniformity of wool, it should be borne in mind that one of the signs of uniform wool is a coarse curling that runs along the entire length of the braid. Presence of a large number of goats with fine wool in a herd cannot be allowed, because with a fiber fineness of more than 50 μm, the wool fleece degenerates into the downy one and the wool becomes fragile, wadded, while losing its characteristic luster sheen and elasticity [16]. Reducing the content of wool fat in wool to 5% and less leads to a decrease in its technological merits, therefore, a high yield of washed wool (over 85%) is also undesirable [14].

In the former USSR, selection and breeding work with Orenburg goats was aimed at increasing the content of down hair in wool and its length while maintaining its valuable quality, i.e., fineness. For this, lower-class females of the Orenburg breed were crossed with Soviet Mohair males to obtain crossbreeds of the first generation. Also, in low-yielding herds of the Orenburg goats, in order to raise down hair productivity and quality, crossing with the Don breed was carried out [14].

At present, the breeding strategy for improving the Orenburg down-hair breed is implemented by the method of purebred goat breeding and is aimed at producing animals with a high yield of long down hair [22]. Purebred breeding is used to keep and improve the breed *inter se*. At the breeding plants and farms, only purebred breeding is used. In order to preserve genetic diversity within the framework of purebred breeding, so called “blood refreshing” is used, i.e., sires for mating are employed from the same breed as dams, but from other farms. Purebred breeding can be used on commercial farms in cases where there are goats of desirable breeding value [14].

When breeding the Orenburg goats, methodical selection is implemented in improving their herd and allocating special selected groups in the herd as intended for their further efficient use and transformation of the herd by desirable phenotypes. Effect of this purposeful breeding program depends on the number of selected characteristics: the more traits are taken into account in the selection, the less selection efficiency. Based on this, at the farms of the Orenburg Oblast, selection by phenotype and partially by genotype is carried out considering two main traits, i.e., weight and length of down hair [22,28].

The selection of Orenburg females is subject to two stages. At the first stage, when goat kids are weaned off their mother, a flock of selected animals is formed based on live weight, livability, and phenotype (according to the breed standard). At the second stage, the main attention is paid to the down hair length and weight, and the nature of the coat. Preference is given to animals with thick, long and uniform down hair that is equal to or slightly shorter than the guard hair. During the period of cashmere wool combing, the down hair yield is taken individually at the first and second combing. The completed herd turnover makes it possible to form a highly productive breeding herd through use of yearlings. This technique has been introduced since 1985, and all the breeder flocks currently are formed through yearlings, which has a positive impact on the performance of the created flocks. As goats grow, their down hair productivity increases, being 190 g in goats, 318 g in yearlings, and up to 475 g in dams [16,28]. The down hair length in the largest part of yearlings and dams is 6.5 cm. The greatest down hair yield is obtained from dams at the age of 4–6 years. With a further increase in the age of animals, a reduction in down hair productivity is observed. At the age of eight years, the down hair yield is 90–95% of its largest value, which is due, first of all, to age-related physiological changes in the body of animals. Thus, there is an advantage in the selection of goats for two main traits, i.e., the weight and length of the down, as compared with the selection for a set of traits [28].

5. Differences in coat appearance and structure

Currently, at the farms of the Orenburg Oblast, animals are selected by phenotype using the following traits: color, weight and length of down hair [21]. Pushkarev [35] identified three production types in Orenburg gray goats (i.e., Orenburg, desirable, and down-hair ones; Figure 5, Table 1) and two types in white goats (i.e., Orenburg white and desirable white ones; Table 1).

Figure 5. The main coat types in the Orenburg gray down-hair goats: (A) Orenburg type, (B) desirable type, and (C) down-hair type (author's photo).

Table 1. Characteristics of down-hair productivity and quality in goats of various coat types (according to [35])

Indicators	Coat type				
	Gray			White	
	Orenburg	desirable	down-hair	Orenburg white	desirable white
Length, cm	3–6.5	6–8	7–10	5–7.5	6–9
Fineness, µm	14–15	15–17	18–20	16–17	16–19
Weight content of down fibers,%	30–45	45–60	50–70	45–50	45–60
Down hair yield, g	250–400	450–600	500–700	450–550	500–600
Female weight, kg	44–46	42–45	42–44	43–45	42–45
Male weight, kg	75–78	72–76	70–75	72–76	70–74

The first type, Orenburg one, is characterized by the guard hair that is much longer than the down hair. The down hair in goats of this type is reliably protected from precipitation and sunlight by a longer coarse guard hair, with the down hair color ranging from dark gray to light gray. In goats of this type meat quality properties are well pronounced [29,35]. For the second, desirable, type, the down hair is equal in length to the guard hair or somewhat inferior to it, and the down hair color varies from dark gray to light gray. Goats of this type also have well-pronounced meat quality characteristics [35]. The third, down-hair, type has the down hair that outgrows the guard hair and forms braids, and the down hair color is gray or light gray. Animals of this type are characterized by satisfactory meat quality traits [35]. The fourth, Orenburg white, type is also characterized by the down hair that is longer than the guard hair and forms braids, and the down hair color is white. Good meat quality properties are inherent in this type. The fifth, desirable white, type has the down hair that is equal in length to the guard hair or slightly inferior to it, with the white down hair color. Meat characteristics in this type of goats are pronounced satisfactory [35]. When comparing performance traits of the different coat types, goats of the third type seem preferable in terms of fiber characteristics and down hair yield among the gray animals, while the fifth type looks superior over the fourth one among the white goats (Table 1). At the same time, the types do not differ significantly in the live weight of both females and males.

Petrov et al. [36] investigated three different types of goats in detail in the experiments executed in the Donskoy Agricultural Production Company (collective farm) in the Orenburg Oblast. The down hair classification of white goats was expanded and attributed to the same three categories as those in gray Orenburg goats (shown in Figure 5), i.e., the Orenburg, desirable and down-hair types of coat. The data obtained as a result of the experiment showed that goats of the Orenburg type of coat (i.e., group I) had the highest live weight. According to the results of individual cashmere wool combing, it was revealed that a larger fleece was obtained from goats of the down-hair type of coat (i.e., group III). The latter surpassed goats of the Orenburg type (group I) for this trait by 34.9%, and goats of the desirable type (group II) by 7.1%. Longer down hair was also observed in goats with the down-hair type of coat, while being 24.5% more than in group I goats, and 19.3% more than in group II goats. The study of the structure and weight composition of the coat showed that it was heterogeneous and consisted of fluff, guard hair and a small amount (up to 1%) of transitional hair. Their percentage was subject to significant fluctuations in the studied animals. The maximum content of down hair in the coat, as well as the absolute strength of the down fiber, was observed in goats of the down-hair type of performance, however, in terms of specific strength, goats of the Orenburg type of productivity had the best indicators. Thus, goats of the Orenburg type of coat had a large live weight, thinner down hair suitable for the manufacture of high-quality products, and maximum specific strength. Female peers of the down-hair type had greater values of fleece, its length and content in the coat, as well as absolute strength of down hair. Animals of the desirable type occupied an intermediate position by many of the traits studied.

Another study [37] was aimed at exploring factors that affect the quality of down hair in purebred gray goats, purebred white goats, as well as crossbred white goats of the Orenburg and Don breeds. The cortical layer of the down hair is much thicker than the scaly one, and the strength, extensibility, elasticity and feltability of the down hair depend on it. In turn, the scaly layer plays a protective role and gives the fiber luster sheen. Petrov [37] found that the highest felting ability, i.e., wool mass density after its felting, had down fibers in goats of group I and amounted to 263 g/cm^3. They surpassed group II by 6.9%, and group III by 9.1%. The study of the shapes and sizes of down fiber scales in goats of the experimental groups demonstrated that in gray down fibers (group I) they had an annular shape and were arranged in a tile-like manner along the fiber, while the outer jagged edges of the scales protruded above the surface of the fiber. Scales of white down fiber (groups II and III) also had an annular shape, but their arrangement was mosaic, i.e., the edges of the scales did not protrude or almost did not protrude above the surface of the fibers. Measuring the length of the scales, namely, the part not covered by other scales, revealed that the longest were the scales of the white down fibers in goats of group III. As a result of the study, it was established that in goats with high down productivity, down fibers were longer and coarser as compared to low-productive animals with shorter and thinner down fibers. When evaluating the down hair properties in white, gray and crossbred goats, it was recommended to breed preferably white goats of the Orenburg breed, their down hair being superior to that in gray goats in terms of absolute strength and elasticity/resiliency properties, with a lower felting ability. To improve the physical properties, i.e., absolute strength and elongation of down fibers, a single crossing of low-productive white goats of the Orenburg breed with white goats of the Don breed was suggested followed by mounting the resulting crossbreed females with white purebred males of the Orenburg breed [38].

6. Relationship of the elemental composition of wool with productive traits

Of particular interest in terms of the development prospects of down-hair goat breeding are works aimed at identifying the relationship between the elemental status of coat and down hair productivity [39]. To determine the elemental status of an animal body, it was proposed to use wool as a test object, since data on the chemical composition of wool make it possible to reliably identify the ecological relationships of farm animals with the geochemical habitat [40]. Wool is an easily accessible biological material, with its sampling being simple and painless. The mineral composition of the coat, as an indicator, testifies about the concentration and activity of chemical elements in other organs and tissues of the body and reflects the elemental status of goats [41]. In this regard, the assessment of the elemental status of the goat coat using a list of elements provides a comprehensive assessment of the state of body’s metabolism [42]. This is determined both by the close relationship between the concentration of trace elements in the coat and blood of goats, and the information value of goat down hair as a long-term parameter for assessing the general state of the mineral metabolism of an animal [43].

A comparative assessment of the elemental composition of goat wool was carried out by Kharlamov et al. [44] in individuals with different down hair performance. In the course of the study, it was possible to identify a significant difference in the concentrations of elements depending on the fleece amount. Thus, in the wool of goats with minimal down hair productivity, elevated concentrations of Mg, Na and Se were observed as compared to the group with average performance, while concentrations of Ca, Cd, Co, Mg, Pb, Si, Sr and V were also greater than those in the group of individuals whose down productivity was the highest. The level of Ag, on the contrary, was the lowest in the group with the minimum productivity. It was established that the elemental composition of the down hair of white goats of the Orenburg breed was in close relationship with productive traits. This is confirmed by significant correlations for many of the studied elements, enabling to use the indicators of the down hair mineral composition when predicting the down performance of goats.

7. Genetic markers

Breeding programs based on molecular genetic methods are attracting increasing attention, primarily because it is difficult to improve some traits using traditional breeding techniques (e.g., [45]). Genome-wide association studies (GWAS) and solving the problem of further improving animal production and the quality of manufactured products requires a better understanding of the structure and functions of farm animal genomes and the mechanisms of their interaction with paratypic (environmental) factors [16,46]. Goat genetic resource characterization studies have used a variety of methods to explore intra-breed genetic diversity, demographic factors, and inter-breed relationships. Immunogenetic studies, microsatellites, also known as STR markers, and markers based on single nucleotide polymorphisms (SNPs) are the most widely used in goat research [21,47].

7.1. Immunogenetic studies

Immunogenetics is based on the detection of erythrocyte antigens of animals using specific sera, i.e., reagents for one animal species. In the study of Ekimov [48], immunogenetic methods were used to identify genetically determined and codominantly inherited types of polymorphic proteins and enzymes that did not undergo changes in postnatal ontogenesis in Orenburg goats. It was possible to establish that the allele pool of the Orenburg down-hair breed is a relatively independent genetic system. Goats of the Orenburg breed were characterized by a high polymorphic state of the hemoglobin locus (*Hb*) that has two allelomorphs in its spectrum, HbA and HbB. At the transferrin locus (*Tf*) in goats of the Orenburg down-hair breed, three variants were discovered including two “fast” alleles, TfA and TfB, and one “slow” allele, TfC. Enzymatic systems of arylesterase (AEs) and alkaline phosphatase (Ap) were also examined in goats of the Orenburg down-hair. The former was controlled by two autosomal alleles, AEsB and AEsH. The distribution of frequencies between the AEsB and AEsH alleles in goat subpopulations was relatively proportional. Comparison of the frequencies of alleles that determine the synthesis of alkaline phosphatase revealed a high frequency of occurrence of the ApB allele.

7.2. Microsatellite (STR) markers

Microsatellites are one of the main molecular markers used to identify, characterize and analyze the genetic associations and diversity of domestic animals (e.g., [49,50]) as also explored in goats by different research teams around the world (e.g., [51]). By performing a multiplex analysis that included 10 microsatellite (STR) markers (*INRA006*, *ILSTS087*, *INRA063*, *CSRD247*, *FCB20*, *ILSTS19*, *INRA23*, *ILSTS011*, *MAF065*, and *SRCRSP005*), Kharzinova et al. [52] managed to identify 93 alleles in a survey of five Russian goat breeds, with all loci being polymorphic. According to the results of the study, the Orenburg and Soviet Mohair breeds were characterized by the least genetic distance. Assessing the effective allele number did not reveal significant differences between goats of the Orenburg, Tajik Mohair, Saanen and Soviet Mohair breeds. Values of the effective allele number per locus varied from 4.248 (Tajik Mohair) to 4.851 (Orenburg). At the same time, genetic equilibrium was observed in all breeds. There was a clear separation of the two phylogenetic tree branches conforming to breeds of domestic (Orenburg, Soviet Mohair and Tajik Mohair) and foreign (Saanen and Alpine) origin.

Selionova et al. [53] assessed the genetic diversity and genetic distances between mohair and down-hair goat breeds raised in the North Caucasus (Karachai, Dagestan Down-hair, Dagestan Mohair), Siberia (Soviet Mohair) and the South Urals (Orenburg), as well as between three wild goat species, i.e., Siberian ibex (*Capra sibirica*), bezoar ibex (*C. aegagrus*), and West Caucasian tur (*C. caucasica*) using 16 microsatellite loci. Karachai goats were characterized by the highest genetic diversity, with the average allele number per locus being 9.1 vs 6.5–7.5 in other breeds. The Orenburg breed demonstrated the least values of genetic diversity parameters as compared to other breeds and wild species. The formation of three clusters was revealed: (1) populations of the West Caucasian tur, (2) populations of the Siberian ibex, and (3) breeds of domestic goats, while there was a small genetic distance between the Orenburg and Soviet Mohair goats. Populations of the bezoar ibex were localized at the root of the third cluster, suggesting their participation as an ancestral form of domestic goats.

Using 14 microsatellite markers, Beketov et al. [25] studied the genetic diversity, relationships and genetic drift among three breeds and seven populations of mohair and down-hair goats in Central and Middle Asia. The parameters of allelic and genetic diversity in five native Mongolian populations (Gurvan Egch (South Gobi), Darkhat, Burakh Zavkhan, Ulgiy Uulan, and Altai Uulan breeds), two indigenous Tuvan populations, Soviet Mohair and Tajik Mohair breeds, and the Orenburg down-hair breed were produced. The Orenburg goats showed the least genetic diversity values relative to other breeds and a closer relatedness to Mongolian (South Gobi) and Soviet Mohair goats. Applying the method of principal component analysis, two main groups of goats were identified, with one combining predominantly Mongolian aboriginal populations, and the other one involving Middle Asian goat breeds (along with the Orenburg breed). Local Tuvan populations were divided between the two groups. The data obtained suggested presence of correlated genetic relationships between the investigated populations and breeds of mohair/down-hair goats and their geographical distribution.

7.3. Mitochondrial DNA (mtDNA) polymorphisms

Molecular genetic surveys based on mtDNA polymorphisms are widely used to clarify origins, study domestication processes and investigate the migration routes of domestic goats and their wild relatives, as well as to establish relationships via maternal lineage. Deniskova et al. [15] examined D-loop sequence variability in seven Russian goat populations. The Orenburg breed was characterized by a lower genetic diversity in comparison to other breeds. The distribution of haplotypes in the groups of Russian goats partly reflected their geo-evolutionary relationships and probably conformed to their established breed status. The three officially recognized breeds, Altai Mountain, Orenburg and Soviet Mohair, were characterized by the presence of specific breed haplotypes. Along with the expected predominant grouping of Russian goats, including the Orenburg breed, with haplogroup A carriers, proximity to three other haplogroups (C, D and G) could indicate different migration routes, through which animals got to the territory of modern Russia. In addition, based on the results obtained, it was suggested that haplotype identification can be considered as a useful tool for developing management and conservation programs for native goats raised in neighboring, partially overlapping habitats.

7.4. SNP markers and GWAS

SNP studies became widespread even at the early stages of the development of DNA diagnostics for farm animals, since it is this type of variability that underlies the polymorphism of genes associated with economically important traits (e.g., [54]). The development of high-throughput genotyping technologies has made SNPs the dominant type of DNA markers in the study of farm animal genomes (e.g., [45,55]). Currently, SNPs are considered the preferred marker type for GWAS and genomic evaluation to establish relatedness between individuals, determine the degree of inbreeding and hybridization, high-resolution genetic mapping, and more complete characterization of genetic resources [56–59]. GWAS approach has become an effective strategy to identify genetic markers for important economic traits in domestic animals [60–62]. The application of GWAS in goats was preceded by the large-scale work of the International Goat Genome Consortium [63] on the implementation of several research projects related to the complete sequencing of the genome of this small ruminant species [64]. As part of the AdaptMap project, 4653 animals were initially genotyped in 148 goat populations from 35 countries on five continents [65]. The developed version of the SNP panel was based on the analysis of differences in 12 million SNP variants identified in the genomes of Saanen, Alpine, Creole, Boer, Katjang, and Savanna goat breeds. Further validation of the SNP distribution was performed on 10 other goat breeds. As a result, 52,295 SNPs were selected that were successfully used to generate the goat 52K SNP BeadChip (Illumina, Inc., USA). The development of DNA chips has significantly expanded the possibilities for identifying loci under selection pressure [66].

The analysis of genetic diversity by Deniskova et al. [67,68] gave an idea of the origin of some local goat breeds in Russia. Based on the results of genotyping performed using the Illumina Goat SNP50 BeadChip, a genetic relationship between the Orenburg and Altai Mountain breeds was established. At the same time, clustering of local and global breeds demonstrated a close genetic relationship between Russian local and Turkish breeds, which apparently arose as a result of an admixture process through postdomestication. The Altai Mountain and Altai White Down-hair breeds showed a common genomic background while including admixture traces from the Soviet Mohair and Orenburg breeds. The results of the described studies contribute to understanding the genetic relationships of the Orenburg breed with goats from Western Asia and Eurasia, and also confirm the uniqueness of the breed's allele pool that represents a complex dynamic system. The inbreeding coefficient F_{IS} in this breed was 0.001, though insignificant, with 95% confidence interval being [–0.001; 0.003]. The genomic inbreeding coefficient based on the runs of homozygosity (F_{ROH}) was also low (0.033), while heterozygosity (both observed and unbiased expected) was high (0.403). The Orenburg breed was also characterized by high values of the effective population sizes estimated for three, five, ten and 50 generations ago as follows: Ne_3 = 414, Ne_5 = 511, Ne_{10} = 600, and Ne_{50} = 1226 [68].

7.5. Candidate genes

One of important aspects of genomic research using SNPs is the identification of candidate genes associated with economically useful traits in farm animals (e.g., [69–71]). Based on genotyping performed on goats from eight populations, Wang et al. [72] reported several genes under positive selection pressure. The gene for agouti signaling protein (*ASIP*) was associated with coat color, and the gene for fibroblast growth factor 5 (*FGF5*) was related to wool performance. In a further study [73], editing the *FGF5* gene in goat embryos resulted in an increase in the number of secondary hair follicles and fiber length. FGF5 is a secreted signaling protein, and its expression is found in hair follicles of wild-type mice as localized in the outer root sheath during the anagen VI phase of the hair growth cycle [74]. These data suggest that FGF5 acts as an inhibitor of hair elongation. The results of many studies [75–78] confirm the positive association of the *FGF5* gene with cashmere performance and the expediency of its inclusion in down goat breeding programs among other candidate genes (Table 2).

Table 2. Candidate genes for cashmere traits in goats

Candidate gene	Annotation	Association	References
		Cashmere properties	
FGF5	fibroblast growth factor 5	Promotes an increase in the number of secondary hair follicles and fiber length	[72,73,75–78]
LHX2	LIM homeobox 2	Stimulates hair follicle activity and control fiber growth	[72,79–81]
PRL	prolactin	Influences the growth and shedding of cashmere fibers without adversely affecting fiber diameter	[82–86]
FGF9	fibroblast growth factor 9	Modulates the regeneration of hair follicles	[72,87,88]
WNT2	Wnt family member 2	Mediates and regulates of Wnt signaling, involved in the initiation of hair follicles	[72,89,90]
KRT39 *KRT74*	keratin 39 keratin 74	Members of the superfamily of intermediate filament proteins; positively correlated with hair length in cashmere goats	[91]
WNT10A	Wnt family member 10A	Involved in Wnt signaling; associated with hair follicle development	[92]

CSN3	casein kappa	Involved in lactation and protein stabilization, located in extracellular space; associated with hair follicle development	[92]
		Coat color	
MC1R	Melanocortin 1 receptor	Regulates the synthesis of eumelanin and pheomelanin in mammalian melanocytes	[72,93–96]
ASIP	Agouti signaling protein	Melanocortin-1 receptor gene antagonist to stimulate pheomelanin synthesis	[72,97–99]

According to Geng et al. [79], it is implied that Lhx2, a member of the LIM homeobox transcription factors, can stimulate hair follicle activity and control fiber growth. Immunohistochemical localization showed that Lhx2 is expressed in secondary hair follicles. Analysis of the expression profiles of Lhx2 mRNA at different stages of development in secondary hair follicles revealed that the highest expression was found out at the anagen phase, and the lowest at the telogen phase [79,80]. Expression of Lhx2 mRNA and protein was unchanged throughout the developmental cycle in secondary hair follicles. These data have led to a better understanding of Lhx2 function and suggested that Lhx2 cyclic expression may play an important role during the development of secondary hair follicles in cashmere goats [81].

The gene for the polypeptide hormone prolactin (*PRL*) is a potential candidate gene for cashmere traits in marker-assisted selection. PRL concentration is associated with wool or cashmere traits [83]; its seasonal variations may determine the pattern of enzymatic activity and influence the growth and shedding of cashmere fibers. Shamsalddini et al. [85] showed that the CC genotype had the longest fibers compared to the AA and AC genotypes (p < 0,05), while there was no significant association between the *PRL* gene genotypes and fiber diameter. These results imply that the *PRL* gene polymorphism can be used as a molecular marker to improve fiber formation without adversely affecting fiber diameter [82,84,86]. In the *POU1F1* gene, a positive regulator for *PRL*, a polymorphism at 3’ UTR was identified as a putative molecular marker for senior cashmere yield [100].

Fibroblast growth factor 9 (Fgf9) originally produced by gamma delta T cells is involved in hair follicle regeneration caused by skin injury. Decreased Fgf9 expression reduces the wound-induced hair neogenesis. Contrariwise, overexpression of Fgf9 leads to a 2–3-fold augmentation in the number of newly formed hair follicles. Gay et al. [87] and Wier and Garza [88] found that Fgf9 from gamma delta T cells induces Wnt expression and ensuing Wnt activation in wound fibroblasts. By virtue of a peculiar response mechanism, Fgf9 is subsequently expressed by activated fibroblasts, thereby enhancing Wnt activity in the wound dermis in the time of a critical phase of skin regeneration. The gene for Wnt signaling pathway-related factor Wnt2 (*WNT2*) is a key mediator and regulator of Wnt signaling and is involved in hair follicle initiation [90]. These two genes may explain the cyclic growth of cashmere fibers in cashmere goats [72,89].

Two genes, melanocortin 1 receptor (*MC1R*) and *ASIP*, are identified as main hereditary factors associated with goat coat color. MC1R plays a key role in regulating the synthesis of eumelanin (black/brown) and pheomelanin (red/yellow) in mammalian melanocytes [95,96,100]. Previously known as *Extension* locus, this gene encodes the melanocortin 1 receptor, some functional mutations of which cause the permanent activation and lead to black coat color, while other inactivating mutations cause red coat color in various mammals [92]. ASIP plays an important role in mammalian pigmentation as a melanocortin-1 receptor gene antagonist to stimulate the synthesis of pheomelanin, another main pigment that gives mammalian coat color [97–99].

Because there has not been any study that would identify any candidate genes of interest in the Orenburg goats, attempts to conduct appropriate research would be highly desirable for elucidating relevant gene variation underlying peculiar performance traits in this breed.

8. Conclusions

The Orenburg goat breed is the brainchild of centuries-old folk selection, clearly distinguished by its special virtues and phenotypic features among other small ruminant animals. Down-hair goat breeding is of great economic importance not only for the Orenburg Oblast, but for the whole of Russia. Among the down-hair got breeds available in Russia, the down hair of Orenburg goats has the highest quality. This is predetermined by the specific natural and climatic conditions of the Orenburg region. The down hair of Orenburg goats is elastic, soft, extremely light, equal in length, has low thermal conductivity and good spinning properties, while being able to fluff well and give a thick, even felt [16,22,27,28].

DNA technologies are efficient instruments in analyzing the structure of the gene pool of local breeds in order to preserve biodiversity. Molecular genetic markers can be used for the directed selection of parental pairs from a limited number of individuals in a closed herd during long-term breeding *inter se* to avoid inbreeding depression [7]. Although at present there is no data on the practical use of genetic markers in the breeding of the Orenburg down-hair breed, the application of this approach can provide additional opportunities for studying the genetic diversity of Orenburg goats. This will also expand the understanding of biological functions of genomic polymorphisms and possible role of genome structural variations in adaptation to the harsh climatic conditions of the Orenburg Oblast, as well as provide a more complete idea of the genetic structure in various production types of Orenburg down-hair goats. Search for genes of economically valuable traits in goats is a fairly promising area of research. It can become the basis for regional programs to maintain the genetic diversity of the Orenburg down-hair breed, an explicit part of the cultural heritage of the region, prioritizing further in-depth genome research and breeding applications for this small ruminant breed in the age of genomics. The future direction of breeding in the Orenburg goats will be fixation of dominant traits and use of favorable genetic variants within the varieties as well as genomic selection within the breed.

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