

GENETIC ASPECTS OF PIGMENTATION OF THE HAIR OF KARAKUL LAMBS OF VARIOUS ORIGINS

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Annotation. This article presents the results of studies of pigmentation of the hair of Karakul lambs of various origins.

A morphological study of the coat of Karakul lambs revealed clear differences in the distribution and shape of pigment depending on the color and genetic origin of the animals. In the hair of Karakul lambs, pigment is found mainly in 2 morphological structures: in the form of individual melanin grains forming linear aggregates of pigment granules, and in the form of voluminous clusters of pigment granules of a fusiform, ellipsoid or spherical shape. The nature of these formations in hair of different colors is different. In dark-colored lambs, melanin is present mainly in the form of linear chains of granules that form structures concentrated in the cortical layer of the wool fiber. In lambs of the sur color, the number of individual granules is small, and the main part of the pigment is concentrated in large aggregates due to the action of the attenuating gene and the peculiarities of the spatial distribution of melanin. In lambs of the cambara color, the pigment has a yellow-orange color and is localized mainly in the form of aggregates, and its size is 2-3 times lower than in black animals. It was found that differences in the morphology and distribution of pigment affect the structural properties of wool fibers and may be related to the interaction of genetic factors that control the intensity and shades of color.

Keywords: Karakul lambs, white and black wool fibers, melanin, eumelanin, pheomelanin.

Introduction. Pigmentation of animal integuments is of great biological importance. Firstly, the pigment is a protective light filter for the body, and secondly, it plays a thermoregulating role, protecting the body from overheating in conditions of high sunlight. The absence or insufficiency of pigmentation in certain conditions leads to disruption of the vital activity of the body, which is confirmed by numerous observations of biologists and animal scientists [1].

The coloring of the skin and hair of wild and domestic animals is very diverse. They depend on the presence of special coloring substances called melanins. There are two types of melanin, eumelanin, which is black or dark brown in color, and pheomelanin, which looks like small, almost equal-sized yellow grains. The combination of these two forms of melanin explains the diversity of mammalian integument colors. The difference in the chemical structure of eumelanin and pheomelanin has not yet been revealed [2,3].

Numerous determinations of the quantitative content of melanin in mammalian hair have shown that hair color also depends on the concentration of the pigment itself. Histological studies were very valuable, on the basis of which it was proved that hair coloring depends not only on the color of the pigment and its amount, but also on the nature of the distribution along the hair shaft [4].

It is known that hair coloring depends not only on the type of melanin and its amount, but also on the nature of its distribution along the length of the hair. Many scientists have studied the morphology of pigmentation of the hair of laboratory animals, fur-bearing animals and sheep using the histological method, which is auxiliary in determining the color differences of hair [5,6].

According to many scientists, the platinum coloration in Karakul sheep is formed by reducing the amount of pigment and distributing it in the form of large clusters concentrated in the cortical layer, on the border with the core. A similar pigment distribution was also revealed by these researchers in Karakul lambs with pink and silver hair coloration [7,8].

In black lambs, the pigment accumulations in the hair are equal in size and have a spindle shape, in lambs the colors of the sur are rounded and oval in shape and vary in size. Karakul, as well as furs of fur-bearing animals, has a variety of colors. The value of the skin depends to a large extent on one or another color [9].

Karakul sheep populations are characterized by a significant variety of colors. In the process of evolution, this diversity contributes to the expansion of the range of hereditary variability, which ensures a high level of plasticity of the species and its ability to adapt to changing environmental conditions [10].

More attention should be paid to histological studies of the colors of Karakul furrows, since the coloring of the hair is one of the important marketable qualities.

The processes of pigmentation of the skin and hair of Karakul sheep were first described by E.Chiani (11) and K.M. Lakhanova (12). They established that the pigment in the skin of black Karakul lambs appears in the third month of embryonic development. It is formed in specific process cells called melanophores and spreads to nearby cells. Concentrating in the bulbs and producing pigment, melanocytes stain the growing hairs.

It can be assumed that this phenomenon is directly related to adaptation to certain living conditions. Animals of white color have a more developed layer of the core. Such a different-quality condition of the hair, depending on the color, is not accidental. It is associated with certain patterns of adaptation of animals to environmental conditions [13].

Many Karakul scientists have noticed a connection between the degree of pigmentation and the viability of gray Karakul sheep. A particularly pronounced weakening of the constitution was observed in animals of lighter shades. Thus, light gray lambs have significantly less vitality than lambs of darker shades. Thus, it was established that the best resin qualities are characteristic of black-colored skins [14].

Histological studies of hair pigmentation in black, brown, and fawn lambs have shown a clear difference in pigment distribution types. While in the hair of black lambs the pigment granules are more uniform, spindle-shaped, densely and evenly distributed, in brown lambs they vary in size and are scattered, round, and oval in shape. They may be larger than in black lambs, but are less densely distributed [15].

The mechanisms of pigment formation in sur-colored fetuses come into play after the invagination of the hair follicle primordia has ended and the growth and keratinization of hair cells has begun. Therefore, hairs with light ends become pigmented closer to the base. However, the pigment granules at the base of the sur hair do not reach the same density as in black hair, which indicates a certain inhibition of melanogenic processes in sur lambs and in subsequent stages of embryonic development. Shifts in the timing of the onset of biochemical processes that ensure melanin synthesis are hereditary, so they are reproduced in offspring, accumulate over generations, intensify, and become constant. This theoretical explanation for the appearance of the sur color in the Karakul breed and the statements of scientists and Karakul breeders about the birth of sur lambs from black sheep allow us to consider the color of sur lambs not as a relict, preserved since the time of domestication, but rather newly formed, having developed in a domesticated state and occurring constantly in our time [16].

Materials and methods of research. The purpose of this study was to identify the morphological features of the distribution of melanin pigment on the hair of Karakul lambs of various colors and origins, as well as changes occurring in its structure during age-related depigmentation. The object of the study was hair samples of Karakul lambs with an established origin, selected from breeding farms in the Turkestan region (Table. 1), which made it possible to take into account the influence of genotypic factors on the analysis results. Hair samples were cut from lambs from the dorsal surface of the body in the sacrum area.

This approach made it possible to take into account genotypic factors that potentially affect the manifestation and nature of pigmentation. Histological analysis was performed using a standard technique using microscopic preparations, which made it possible to study in detail the distribution of pigment granules and the structural features of the hair depending on the color and age of the animals.

The selected hair samples of Karakul lambs were subjected to sequential mechanical cleaning in order to remove surface contamination. They were degreased in a Soxhlet apparatus with sulfuric ether, washed in a hot detergent solution, rinsed first with warm, then cold distilled water and dried in a drying cabinet at a temperature of 105 ° C. The purified samples were stored in a desiccator.

Table 1 – Origin and coloration of lambs from which hair samples were taken

Parentage and coloring of parents		Lamb coloring
Mother	Father	
Black, from black parents	Black	Black
Black, from black parents	Sur golden	Black, Sur golden
Black, from black parents	Sur silvery	Black, Sur silvery
Black I, II generations, from the mating of a black mother with a golden ram	Sur golden	Black, Sur golden
Black I, II generations, from the mating of a black mother with a ram sur silver	Sur silvery	Black, Sur silvery
Black, from black parents	Gray, from a black mother and a gray father	Black, Grey
Sur golden, from both parents sur golden	Sur golden	Sur golden, Black
Sur silver, from both parents sur silver	Sur silvery	Sur silvery, Black
Kambar from black parents or kamar	Gray, from mother kamar and gray father	Pink (guligaz)
Kambar from black parents or kamar	Kambar	Kambar
Pink (guligaz)	Kambar	Kambar, Pink (guligaz)

Histological studies were performed on the hair of newborn, 20-day-old and 5-month-old Karakul lambs of various colors and genotypes with varying pigmentation intensity. The hair of harsh lambs was studied according to the staining zones. For histological studies, hair of the same morphological type (awn) was used.

10-15 hairs were taken from the cleaned and washed sample, laid out on a slide and filled with a drop of molten wax. The slides were cooled to 0 ° C and kept at this temperature for several hours. Then the frozen wax and the hair were separated from the glass, applied to pre-prepared blocks, cooled again and cut using a microtome. With two or three strokes of the microtome razor, the blocks were leveled, and then sections were made, which were transferred from the tip with a brush or a preparation needle onto a slide. The thickness of the sections should not exceed 5-6 microns, since thicker sections cannot be used to study the internal structure of the hair.

The finished micro-preparations were examined under an MBI-1 microscope at a magnification of 600 times (10 X 60), which provided visualization of both individual pigment granules and their aggregates. The severity of pigmentation of the hair of Karakul lambs was determined visually (bonification) and objectively (EPR spectrometry).

The results and their discussion. *Homozygous black lambs.* We found two types of morphological pigment formations in the hair of Karakul lambs of black color - individual pigment granules and their bulk clusters (aggregates).

In the hair of Karakul lambs homozygous for black coloration, a large number of melanin grains are located in both the cortical and core layers, which create the impression of a solid dark brown background at low magnification.

On the longitudinal sections. in the cortical layer, individual granules can hardly be seen,

arranged in long, tightly connected chains running parallel to the length of the hair. There is no pigmentation between the individual granules.

There are also clusters of rod-shaped and spindle-shaped granules in the cortical layer, the length of which is 3-4 times their transverse size. Due to the fact that the size of pigment granules is less than 1 mm, it is impossible to study their shape and size using a light microscope, therefore, first of all, we studied the morphology of volumetric clusters of pigment. The sizes of clusters of pigment granules are shown in Table 2.

Table 2 – Age-related changes in the size of clusters of pigment granules (aggregates) in the hair of black Karakul lambs of various origins

Coloration and genotype of the lamb	The length of pigment accumulations (aggregates)			The width of the pigment accumulations (aggregate)		
	at birth	at the age of 20 days	at the age of 5 months	at birth	at the age of 20 days	at the age of 5 months
	M ± m	M ± m	M ± m	M ± m	M ± m	M ± m
Black, from a uniform black-colored mating	6,3 ± 0,06	4,3 ± 0,03	1,9 ± 0,04	2,2 ± 0,03	1,8 ± 0,01	1,1 ± 0,01
Black, from a mating that is heterogeneous in black color	7,6 ± 0,04	4,7 ± 0,05	1,4 ± 0,06	2,7 ± 0,03	2,3 ± 0,02	0,9 ± 0,03
Black, from a uniform harsh-colored mating	5,2 ± 0,04	3,1 ± 0,02	1,3 ± 0,02	2,3 ± 0,02	1,56 ± 0,03	0,7 ± 0,01

In the future, the offspring obtained from the mating of black-colored producers are conventionally designated as homozygous, while lambs obtained from crossing black queens with sheep of the sur color are considered as heterozygous for black coloring.

It can be seen from the data in Table 2 that the average size of pigment aggregates in the hair of black lambs of different genetic origin is not the same. The largest aggregates are found in the hair of black lambs obtained from a mating with a heterogeneous black color (black x sur). Differences in the size of pigmented aggregates of black hair of lambs of different origins are statistically significant (in all cases, $P < 0.01$).

There are significantly fewer pigment granules in the core layer and their arrangement has the character of a random scattering. The accumulation of granules is usually thicker on the inside of the curl. On the cross sections of the hair, melanin grains form 7-8 concentric circles, as well as clusters of oval and rounded shapes. In the cross sections of the hair tips, the pigment is located in the same way as at the base, but pigment granules do not occur at the very tip of the aggregates.

In 20-day-old lambs, clusters of pigment granules begin to lighten, acquire a brownish hue, pigment aggregates acquire clearly defined outlines, become smaller, but their number does not change significantly.

By the age of five months, lambs, along with a decrease in the size of pigment aggregates, also have a decrease in the number of pigment granules. They are located less densely, free spaces appear between them, devoid of pigment. With age, the process of melanogenesis slows down, and melanocytes of hair follicles produce melanin granules of lighter tones. The number and magnitude of volumetric accumulations of pigment decrease dramatically.

In the hair of lambs with weakened black pigmentation, the concentration of melanin granules and bulky pigment accumulations is the same as in hair with normal pigmentation.

Lambs, heterozygous for black coloration. The hair of black lambs, descendants of black queens and sheep of the sur color, contains significantly less pigment than in black lambs descended from both black parents. On microsections of the hair of black-colored heterozygous lambs, we

noted a less dense arrangement of pigment granules with significantly fewer volumetric accumulations of pigment, but the distribution of melanin granules and volumetric accumulations is the same as in the hair of black lambs obtained from both black parents.

As can be seen from Table 2, the process of pigment destruction is most rapidly intense in the hair of lambs of severe coloration. With age, both the destruction of pigment granules and the formation of more friable pigment aggregates occur: their number decreases, and the granules themselves become lighter. This is the result of a gradual decrease in the tyrosinase activity of melanocytes contained in the hair follicle.

Studies of the hair of black lambs of different genetic nature and different pigmentation intensity have shown that the distribution of pigment along their hair length is identical, but the density of the pigment granules and the size of the volumetric accumulations of pigment (aggregates) are different.

Colored Karakul lambs. Histological studies of the hair of lambs of the colors sur golden, sur silver, cambara and pink were carried out by us, taking into account their origin and color variations in the age aspect. The origin and coloration of the lambs from which hair samples were taken are shown in Table 1.

On the longitudinal and transverse sections of the hair of colored Karakul lambs, both individual pigment granules and their volumetric accumulation are found. The hair of such lambs contains significantly less pigment than the hair of black lambs.

In the hair of lambs, sur colors are golden and silver, cambar and pink pigment are large aggregates of ellipsoid and rounded shapes located along the length of the hair. The gaps between these clusters of pigment are filled with a scattering of small pigment granules. Pigment granules and their voluminous accumulations in the hair of golden and silver sur have a black - brown color, the same as in the hair of black lambs. Pigment granules and their clusters in the hair of kambar lambs and in the brown hair of guligaz lambs have a color close to yellow-orange.

In the hair of silver-haired cows, pigment accumulations have the shape of an ellipse, in golden ones - ellipsoid and rounded, in the hair of lamb flounders - only rounded.

A disorderly scattering of melanin granules is revealed in the core layer of the hair of colored Karakul lambs. Cross-sectional studies of this hair show that most of the pigment is located in the cortical layer, where aggregates are mainly concentrated. It is very rare to find individual aggregates in the core layer.

The hair is harsh, the scattering of pigment granules is very thin, the pigment aggregates are loose and large. Closer to the top of the hair, aggregates of pigment granules are less common and have smaller sizes. Aggregates acquire a mostly rounded shape. The tip of the golden sura hair is filled with a fine scattering of pigment granules, and small rounded aggregates are also found here. At the base of the hair, the aggregates and pigment granules are more dense.

We have not established differences in the size of pigment aggregates in the hair of colored Karakul lambs, depending on their origin, except for the fact that larger clusters of pigment granules are found in light-colored hair, smaller ones in dark hair. The sizes of clusters of pigment granules are shown in Table 3.

Table 3 – The size of pigment aggregates (mc) in the hair of colored Karakul lambs of different shades at birth

Coloring	Length			Width		
	light M ± m	Average M ± m	Dark M ± m	light M ± m	Average M ± m	Dark M ± m
Sur golden	30,6 ± 3,1	19,3 ± 1,2	12,9 ± 1,1	9,3 ± 0,4	8,5 ± 0,6	67,8 ± 0,6
Sur silvery	44,6 ± 3,0	24,9 ± 2,4	16,6 ± 0,8	12,1 ± 0,3	7,9 ± 0,7	6,1 ± 0,4
Brown	10,4 ± 0,5	8,7 ± 0,3	2,6 ± 0,3	8,9 ± 0,1	8,1 ± 0,2	2,1 ± 0,2
Pink (guligaz)	7,6 ± 0,3	6,8 ± 0,2	2,9 ± 0,3	7,2 ± 0,1	6,1 ± 0,3	3,1 ± 0,1

In colored Karakul lambs, aggregates are located thicker in dark-colored hair than in light-

colored hair. The densest accumulation of pigment aggregates and granules is observed on the inner side of the curl. Aggregates in the hair of lambs of the color sur silver are much larger than in the hair of lambs of the colors brown and guligaz, as well as sur golden. The difference in the size of pigment aggregates in the hair of colored and Karakul lambs is highly significant. With age, depigmentation of the hair in colored Karakul lambs proceeds much faster than in black lambs of various origins.

By the age of 5 months, the hairline of colored Karakul lambs is strongly depigmented. By this time, the pigment aggregates have already been almost completely destroyed or are very rare, the scattering of pigment granules is very thin, and occasionally small groups of them are found. The color of granules and pigment aggregates ranges from light brown to light straw. With age, the tyrosinase activity of melanocytes in hair follicles partially decreases, and therefore they produce more friable pigment aggregates and light-colored pigment granules.

The process of depigmentation of the hair of lambs of the cambara color, brown hair of lambs of the guligaz color and the tip of the golden harsh hair proceeds much faster with age than in the base and middle part of the hair of lambs of the sur color. This is due to the presence of yellow-orange pigment in the tip of the hair of golden cows, in the hair of lambs of guligaz coloring, which, apparently, is susceptible to faster decay.

Conclusion. Thus, morphological studies of the hair of Karakul lambs revealed clear differences in the distribution of pigment in the hair, depending on their color and origin.

In the hair of Karakul lambs, pigment is found mainly in 2 morphological structures: in the form of individual melanin grains forming linear aggregates of pigment granules, and in the form of volumetric clusters of pigment granules of a fusiform, ellipsoid or spherical shape. The nature of these formations in hair of different colors is different.

The black lambs' hair is dominated by individual melanin grains, which form a series of concentrically arranged cylindrical surfaces in the cortical part, the longitudinal axis of which runs parallel to the length of the fiber. These cylindrical surfaces have the appearance of chains on the longitudinal sections, and concentric circles formed by melanin granules on the transverse sections. In addition, rod-shaped and ellipsoid clusters of pigment granules are found in black hair, which do not have clear boundaries at the birth of the lamb and acquire clear outlines with age.

The main amount of melanin in black hair has the appearance of linear formations consisting of individual pigment granules, a much smaller part of it looks like bulky clusters.

In lambs' hair, the color of individual pigment granules is significantly less, and the main amount of melanin is represented in the form of large volumetric accumulations. The dark base of the hair of lambs of the sur color contains 9.8 - 10% of the pigment, i.e. about the same amount as in the black hair of heterozygous lambs. The reason for the formation of discoloration of the sur should, apparently, be sought not so much in a decrease in the total melanin content in the hair, as in the distribution of pigment granules in it.

The strength of the curls of colored doodles is weaker than that of black ones, and this is probably explained not only by the pleiotropic effect of color factors, but also by the different distribution of pigment. It is possible that the pattern of pigment distribution at the base of the hair in sur lambs is due to the action of the attenuating gene.

The pigment content in the hair is apparently influenced by other factors responsible for the hereditary transmission of shades of light, medium, and dark. Most likely, this is a combination of a dominant and recessive allele, as it allows, and also explains the inheritance of shades in red-brown lambs (cambar). In flounder-colored lambs, the pigment in the hair is mainly in the form of clusters, and the pigment granules and their clusters are colored yellow-orange, while the granules and clusters of pigment in harsh and black lambs are black-brown. The hair of flounder-colored lambs contains 2-3 times less pigment than the hair of black lambs of various origins. Hair coloring of brown (cambara) Karakul lambs are caused by a different chemical nature of yellow-orange melanin, as well as a smaller amount of it and a peculiar distribution along the length of the hair.

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ШЫҚҚАН ТЕГІ ӘРТҮРЛІ ҚАРАКӨЛ ҚОЗЫЛАРЫНЫҢ ЖҮН ЖАМЫЛҒЫСЫНЫҢ ПИГМЕНТАЦИЯСЫНЫҢ ГЕНЕТИКАЛЫҚ АСПЕКТІЛЕРІ

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Аңдатпа. Мақалада әртүрлі шығу тегі әртүрлі қаракөл қозыларының жүн жамылғысының пигментациясын зерттеу туралы мәліметтер келтірілген.

Қаракөл қозыларының жүн жамылғысын морфологиялық зерттеу нәтижесінде жануарлардың түсі мен генетикалық шығу тегіне байланысты пигменттің таралуы мен формасында айқын айырмашылықтар анықталды. Қаракөл қозыларының шашында пигмент негізінен 2 морфологиялық құрылымда болады: пигментті түйіршіктердің сызықтық агрегаттарын құрайтын жеке меланин дәндері түрінде және фузиформды, эллипсоидты немесе сфералық пигментті түйіршіктердің көлемді шоғырлары түрінде. Жүн талшығындағы бұл түзілімдердің табиғаты әртүрлі түстерде өзгеріп ерекшеленеді. Қара түсті қозыларда меланин негізінен жүн талшығының кортикальды қабатында шоғырланған құрылымдар түзетін түйіршіктердің сызықтық тізбектер түрінде болады. Сур түсті жануарларда жеке түйіршіктердің саны аз, ал пигменттің негізгі бөлігі әлсірететін геннің әсеріне

және меланиннің кеңістіктік таралу ерекшеліктеріне байланысты үлкен агрегаттарда шоғырланған. Камбар түсті қозыларда пигмент сары-қызғылт сары түске ие және негізінен агрегаттар түрінде локализацияланған, ал оның мөлшері қара жануарларға қарағанда 2-3 есе төмен. Пигменттің морфологиясы мен таралуындағы айырмашылықтар жүн талшығының құрылымдық қасиеттеріне әсер ететіні анықталды және түс қарқындылығы мен реңдерін бақылайтын генетикалық факторлардың өзара әрекеттесуіне байланысты болуы мүмкін.

Тірек сөздер: Қаракөл қозылары, ақ және қара түсті жүн талшықтары, меланин, эумеланин, феомеланин.

ГЕНЕТИЧЕСКИЕ АСПЕКТЫ ПИГМЕНТАЦИИ ВОЛОСЯНОГО ПОКРОВА КАРАКУЛЬСКИХ ЯГНЯТ РАЗЛИЧНОГО ПРОИСХОЖДЕНИЯ

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Аннотация. В настоящей статье представлены результаты исследований пигментации волосяного покрова каракульских ягнят различного происхождения.

В результате морфологического исследования шерстного покрова каракульских ягнят были выявлены явные различия в распределении и форме пигмента в зависимости от окраса и генетического происхождения животных. В волосе каракульских ягнят пигмент находится главным образом в 2-х морфологических структурах: в виде отдельных зерен меланина, образующих линейные агрегаты пигментных гранул, и в виде объемных скоплений пигментных гранул веретеновидной, эллипсовидной или сферической формы. Характер этих образований в волосах разных окрасок различен. У ягнят темного цвета меланин присутствует в основном в виде линейных цепей гранул, которые образуют структуры, сконцентрированные в корковом слое шерстяного волокна. У ягнят расцветки сур количество отдельных гранул невелико, а основная часть пигмента сосредоточена в больших агрегатах из-за действия ослабляющего гена и особенностей пространственного распределения меланина. У ягнят расцветки камбар пигмент имеет желто-оранжевый цвет и локализуется преимущественно в виде агрегатов, а его размер в 2-3 раза ниже, чем у черных животных. Было обнаружено, что различия в морфологии и распределении пигмента влияют на структурные свойства шерстяного волокна и могут быть связаны с взаимодействием генетических факторов, контролирующих интенсивность и оттенки цвета.

Ключевые слова: Каракульские ягнята, белые и черные шерстяные волокна, меланин, эумеланин, феомеланин.