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THE INFLUENCE OF AGE ON HISTOLOGICAL PARAMETERS OF GREENLAND NUTRIA HAIR COAT*

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The aim of the study was to evaluate the development of Greenland nutria hair coat including the histology of hair follicles. The skin samples for histological investigation were collected monthly, from central part of ventral and dorsal body side of 3- to 9-month-old animals. It was observed that area of tufts, number of bundles per tuft and number of down hairs per tuft increased with age. Increasing distances between tufts were also noted with age. The thickness and length of guard and down hair and the medulla area increased but cortex area decreased with age. Length of hairs, tufts area and hair number depended also on part of the body and were higher on dorsal part. The back coat was characterized by thicker guard hair. Summing up the results obtained it can be stated that the most beneficial results of coat quality were observed between 6 and 7 months of age. Most of features such as bundle surface, number of down hairs per tuft thickness and length of guard hairs stabilize and no longer improve with age. Moreover, other features such as distance between bundles or thickness and length of guard hair may deteriorate. These results allow a conclusion that the age of six-seven months is the optimal time for slaughter. Histological studies on morphology of nutria skin and development of hair follicles can be useful not only to determine the optimum date for slaughtering and skinning animals, but they could be also the basis for other researches including different methods of breeding, nutrition or administration of pelt and skin quality stimulants.

Key words: nutria, hair coat quality, hair coat development, hair coat histology

Hair coat of fur animals consists of guard hairs – guard and awn hairs and down hairs – transitional and wool hairs. Down hairs are thermal insulation against adverse environmental influences. Guard hairs are a specific scaffold for wool hairs keeping them upright and protecting against negative influence of the external environment, which may cause felting and tangling of hairs. Outer coat hairs are also responsible for color and general appearance of fur on living animal (Brzozowski, 1984). Hairs in

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skin of fur animals are arranged in complex tufts. Each tuft consists of several bundles, which are arranged around guard hairs. There are tufts of varying numbers of bundles (Oznurlu et al., 2009). The guard hair occurs most often in multibundle tufts. There are also individual tufts that do not have guard hair. However, with age it is increasingly difficult to find such arrangement due to the development and expansion of skin areas.

Formation and growth of hair coat begins in mammals already in fetal life (Sick et al., 2006; Wang et al., 2007) and is an extremely complex process which is influenced by both genomic and non-genomic factors, such as nutrition or living conditions (Galbraith, 2010). During development of the skin there are three types of hair follicles. The first during ontogeny arise central primary follicles, and then the lateral primary follicles, from which guard hair will grow in the future. They are accompanied by sebaceous gland, apocrine sweat gland and surrounded by numerous capillaries and nerve fibers. Last arise secondary follicles. Depending on the species of animal they grow in tufts or singly next to primary follicles. The earliest phylogenetic arrangement consists of three primary follicles (one main and two side) which are grouping around secondary follicles (Meyer, 2009). After birth, mature and actively growing hair follicles anchor in the subcutaneous tissue and are periodically recovered through repetitive cycles of spontaneous growth (anagen), regression (catagen) and a resting state (telogen) (Schneider et al., 2009).

There is a variety of techniques, which allow investigating skin and fur coat: from subjective, which require considerable experience in organoleptic methods; to physical methods such as measuring the absorption of radiation by different coat layers in order to evaluate the density and mass of hair; to laser scanning to evaluate their length; to more accurate histological methods (Lohi et al., 1996). Nowadays we use also biochemical methods to find and measure molecules building hairs and skin (Riis, 1998; Hanusova et al., 2000). There are many histological analyses of skin of other animal species like rabbit (Oznurlu et al., 2009), mink (Kondo et al., 2000; Kondo and Nishiumi, 1991), sheep (Mobini, 2012 a, b) or in recent studies even wildlife rodents (Ibe et al., 2014), but few publications addressed the histological structure of nutria skin (Ptak, 1965). Due to the little knowledge and only few publications on the subject it is reasonable to conduct research on histology of nutria hair coat.

The aim of the study was to evaluate the age-dependent structural changes in development of female Greenland nutria hair coat from the third to the ninth month of life including the histology of skin and hair follicles.

Material and methods

Animals and skin samples

Skin samples of 35 female Greenland nutrias of different ages were used as studied materials. Animals were kept on one of the farms in southern Poland. All animals were reared in cage system without access to water reservoirs and fed identically in accordance with the existing standard. Animals were slaughtered between 3 and 9 months of life, 5 individuals per month. After slaughter, the skin was pulled down a bag system, and pre-treating and drying were carried out on the farm, in accordance with applicable standards. The 10 mm diameter skin samples were taken from middle of back (1) and abdominal side (2) of the skin of each animal.

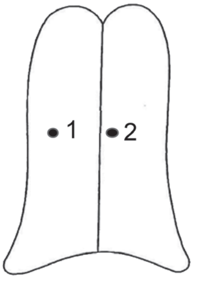

Figure 1. Scheme of nutria skin with marked location of samples collection for histological studies

Histological procedures

Sections of skin were fixed in formalin solution, and then dehydrated in alcohol and embedded in paraffin. So prepared blocks were sectioned by a microtome Leica and prepared in histological slides which were stained with hematoxylin and eosin method for a light microscopy examination. Each block provided 3 histological slides with a thickness of 6–8 µm.

Histological analysis

Morphometric measurements were made using light microscope (Nikon E-600, Japan) equipped with digital camera head. The histological evaluation and measurements were performed on the digital images using computer image analysis software Multi Scan (14.02 version). The study focused specifically on the parameters of hair roots, their size, distribution and structure depending on age and body part. The following parameters were determined: tufts surface (µm^2), distances between tufts (µm), number of hair follicles per tuft, thickness of individual hair types (µm), mean surface of the cortex/surface of medulla ratio in guard hairs, and length of guard and down hairs (mm).

Results

The present experiment showed that bundle size was significantly differentiated according to age and body part (Table 1). Bundles containing only down hairs (Figure 3) were much smaller than those containing guard hair (Figure 2), which occurred in every third bundle on average. They were typical for 3- to 5-month-old nutria. The smallest bundles occurred in the fur of 5-month-old animals and had a surface of 40 000 mm^2, which is associated with the period of rebuilding the structure of the coat from the first to secondary hair coat. With age, the number of down hair increased, leading to an increase in the surface of bundles, which reach a maximum size of approximately 70 000 mm^2 at 7 months of age. By 7–8 months nutria bundles were larger on the back than on the belly side by about 4.3–4.6%. At the age of 9 months bundle size on the back (Figure 4) and belly was nearly the same at 70 000 mm^2.

Table 1. The effect of age on the histological measurements of hair tufts in nutria skin

Age (months)	Tuft surface (µm^2)		Distance between tufts (µm)	
	belly	back	belly	back
3	57666.8±4004.8	64316.8±9711.7	41.0±4.8	79.1±7.8
4	59115.0±9112.7	65892.4±5004.6	56.4±13.5	89.8±20.3
5	40046.4±6721.9	50890.0±4009.8	65.9±12.9	97.7±30.1
6	53136.3±6540.7	57340.2±7429.1	69.7±23.5	102.8±28.3
7	69353.9±17306.9	72500.0±20874.2	90.4±20.6	112.9±39.4
8	69725.4±17953.2	73109.4±21515.3	91.2±25.3	120.5±40.7
9	72561.6±22417.5	72305.1±19613.9	151.0±29.8	169.2±36.5

Figure 2. Microphotograph of hair tuft of 5-month-old nutria, 160x magnification, belly sample
1 – guard hair, 2 – bundles of down hairs, 3 – down hairs, 4 – collagen fibers

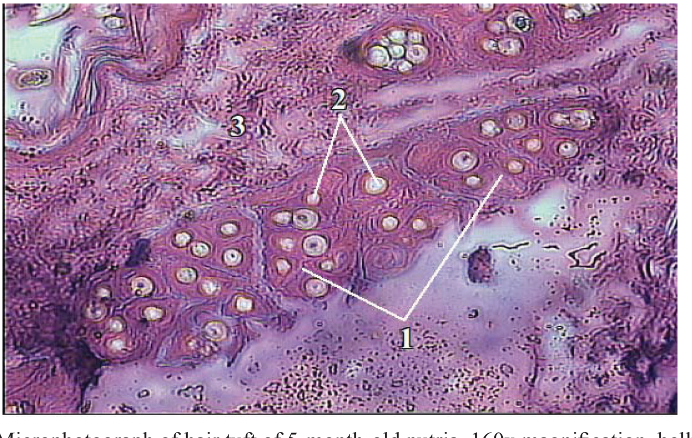

Figure 3. Microphotograph of hair tuft of 5-month-old nutria, 160x magnification, belly sample
1 – bundles of down hairs, 2 – down hairs, 3 – collagen fibers

With age, distance between bundles increased (Table 1). Distances between bundles were greater on the back than on the belly side. It has been found that the distance between bundles was the smallest on 3-month-old animals' belly (about 45 µm) and with age increased to 150 µm. On the back the distance has grown from 60 µm at 3 months to 169.2 µm at 9 months of life. The fastest growing distance between bundles has been seen during the last month of life.

The analysis of nutria pelt showed a similar number of tufts per bundle according to the part of the body and age. The smallest number of tufts was found for 3- to 4-month-old nutria (Figures 2 and 3), and the largest for 9-month-old nutria on the back (Figure 4). The content of down hairs per tuft ranged from 20 to 30 hairs (Table 2). The number of down hairs per tuft was the smallest for 4-month-old nutria (about 20), probably because it is the ending time of primary to secondary hair coat replacement. From the fifth month of life the number of down hair increased, which was probably associated with regrowth of secondary hair during second hair replacement. Number of down hairs per tuft increased with age and it was the highest for 8- to 9-month-old individuals – more than 200 hairs. Number of down hairs per tuft was 23% higher on the back than on the belly side.

Table 2. Changes in the histological parameters of hair distribution in the Greenland nutria skin under the influence of age

Age (months)	Number of bundles per tuft		Number of down hairs in bundle	
	belly	back	belly	back
3	5.0±1.3	4.0±0.7	21.3±4.5	23.1±10.4
4	4.0±0.7	4.5±0.8	20.0±12.6	20.4±6.1
5	7.0±2.0	5.0±2.9	22.7±12.5	25.6±4.5
6	7.0±1.8	6.0±0.8	28.3±14.2	28.7±8.7
7	6.0±1.4	7.0±2.3	30.0±11.0	28.1±4.7
8	6.5±2.7	7.0±2.0	31.0±13.1	29.3±7.1
9	7.0±1.0	9.0±1.8	30.2±12.9	30.4±10.2

Figure 4. Microphotograph of 9-month-old nutria skin, 160x magnification, back sample
1 – guard hair, 2 – awn hair, 3 – tufts of down hairs

The thickness of the down hair on belly ranged from about 16 to 18.5 μm, while on the back from 18.5 μm to 21.5 μm (Table 3). The difference in hair thickness, depending on body part, was the highest for 3- and 9-month-old animals and it was about 14%. Between 4 and 8 months of age the difference in the thickness of the down hairs was smaller (less than 10%). The surface of the down hair increased with age and was higher on the back. Thickness of guard hair for young animals amounted to about 120 μm on belly site to 135 μm on back site. Thickness of guard hairs for adult animals was approximately 142 μm on the belly and 150 μm on the back site. The thickness of guard hairs increased to 7 months of age and after that decreased. The greatest difference in thickness of hairs between back and belly sites has been observed around 4 months of life, when guard hairs ranged from 120 μm on the belly to 145 μm on the back. The surface of the guard hair as well as the down hair was higher on the back site. The awn hair was characterized by greater variation in thickness and surface area depending on the age and place of sample collection (Table 3).

Table 3. The results of morphometric measurements of awn hairs and down hairs depending on age and body part

Age (months)	Awn hair		Down hair	
	belly	back	belly	back
3	1857.2±223.4	1643.9±152.3	198.9±62.4	272.8±46.7
4	1961.3±844.2	2109.1±683.0	242.5±70.9	297.0±81.5
5	2914.1±652.3	2587.8±930.3	258.8±103.5	295.2±102.7
6	3200.2±798.5	2497.5±829.6	260.0±94.8	301.9±104.2
7	3206.2±1061.6	3552.0±430.0	258.0±67.7	302.7±98.5
8	3012.3±993.4	3977.8±890.2	267.8±62.8	308.6±105.7
9	3009.9±1237.2	3271.2±759.4	272.7±79.4	363.2±69.8

Table 4. Morphometric measurements of nutria guard hair depending on age and height of cross-section

Age (months)	Hair thickness (μm)		Hair surface (μm^2)		Medulla surface (μm^2)		Cortex surface (μm^2)		Medulla to cortex ratio	
	bulb	root	bulb	root	bulb	root	bulb	root	bulb	root
3	69.9 ±6.4	135.9 ±27.2	4529.4 ±404.6	18470.1 ±7403.3	1704.7 ±603.9	6144.5 ±1527.4	2824.7 ±450.4	12325.6 ±3690.2	1:1.6	1:2.0
4	71.2 ±6	150.5 ±30.9	5069.4 ±398.2	22648.5 ±3209.4	1766.2 ±899.5	6261.0 ±2975.8	3303.2 ±987.2	16387.5 ±5092.5	1:1.9	1:2.6
5	73.5 ±15.4	152.3 ±29.3	5402.3 ±469.0	23195.3 ±8535.6	1884.8 ±592.1	4981.6 ±2104.1	3517.5 ±1260.9	18213.7 ±3988.0	1:1.9	1:3.4
6	80.9 ±10.8	155.3 ±39.5	6544.8 ±1016.1	24117.1 ±8341.4	2289.0 ±874.2	3218.3 ±1965.3	4255.8 ±971.0	20898.8 ±4136.3	1:1.9	1:6.5
7	87.0 ±5.4	156.9 ±78.1	7569.0 ±858.4	24617.6 ±8672.2	2640.7 ±590.8	2367.3 ±3981.0	4928.3 ±1297.2	22250.3 ±5439.2	1:1.9	1:9.4
8	87.4 ±16.0	160.9 ±67.2	7638.8 ±818.9	25881.8 ±5304.7	2662.0 ±1027.1	2425.8 ±4846.8	4976.8 ±1520.3	23456.0 ±7439.1	1:1.9	1:9.7
9	103.6 ±40.2	161.0 ±87.5	8427.6 ±1070.1	25921.0 ±5565.9	3120.7 ±956.9	2447.2 ±3476.9	5306.9 ±1752.7	23473.8 ±6596.0	1:1.7	1:9.6

There was also found the effect of age and cross-section height on the total surface of the guard hair, the cortex and medulla (Diagram 1). The surface of guard hair near the bulbs increased with age from 4 500 mm^2 in the third month to 8 400 mm^2 in the ninth month (Table 4). The ratio of the cortex to the medulla near the bulbs has not changed with age. The surface of medulla increased from 1700 mm^2 in the third month to 3100 mm^2 in the ninth month, while the surface of cortex increased from 2800 mm^2 in the third month to 5300 mm^2 in the ninth month. The surface of guard hair on root height slightly increased with age from 18 400 mm^2 in the third month to 24 600 mm^2 in the ninth month. The thickness of the cortical layer was increased at the height of the root. This ratio ranged from 1:2 for 3-month-old nutria (Figure 5) to 1:9 for the oldest animals (Figure 6).

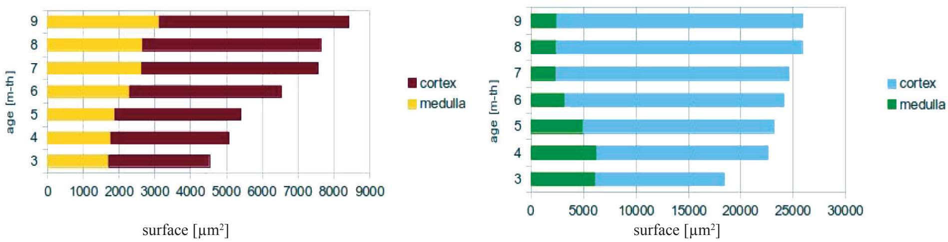

Diagram 1. Surface of the cortex and medulla in the guard hair follicles (a) and roots (b) in female nutria of different age

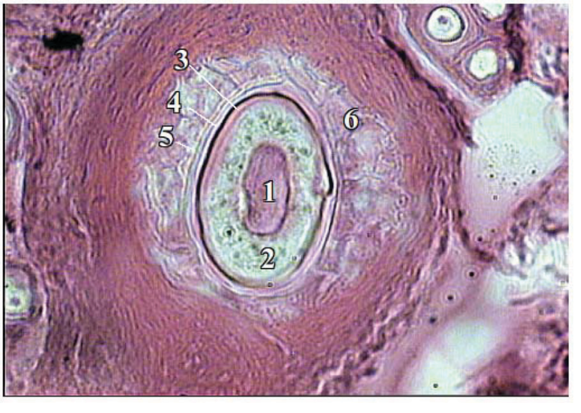

Figure 5. Microphotograph of transversal section through root of guard hair of 3-month-old nutria, 320x magnification, belly sample
1 – cortex, 2 – medulla, 3 – cuticle, 4 – inner root sheath, 5 – outer root sheath, 6 – connective tissue capsule

The next parameter evaluated in the present study was the length of down and guard hair depending on age and body part (Diagram 2). Both types of hair were longer on the back than on the abdominal region. Down hair grew consistently from 8.6 mm in the third month to 15.4 mm in the ninth month. Down hair growth was the greatest between 5 and 6 months on belly site, while on the back between 7 and 8 months. Guard hair was on average about twice shorter on belly site than on the back site. The largest increase in length occurred between 5 and 6 months of age, when the length of the hair on the back was 70 mm, and on belly 35 mm. In subsequent months of life, a slight decrease of growth was noted, resulting probably from the period of molting, and length stabilization. In the eighth month guard hair on the back was only 60 mm and on the belly site about 30 mm.

Figure 6. Microphotograph of transversal section through root of guard hair of 9-month-old nutria, 320x magnification, back sample
1 – cortex, 2 – medulla, 3 – connective tissue capsule

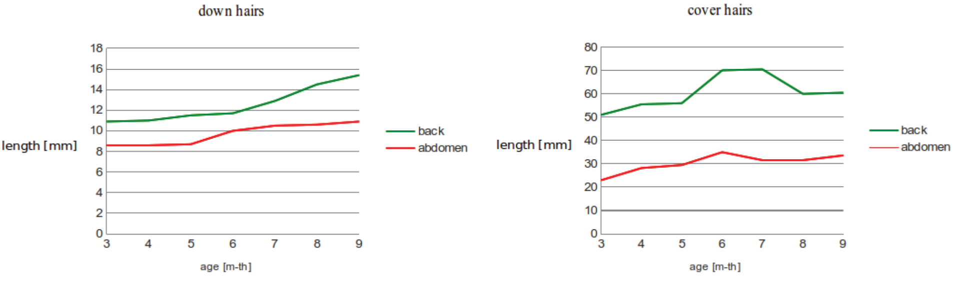

Diagram 2. The length of Greenland nutria coat depending on age and body part

Discussion

Nutrias are born with well developed, dense, brown primary coat. For this reason coypu differ from most other mammals with a shorter period of pregnancy, for example foxes or rabbits, where newborn individuals are generally infirm, blind and naked (Skrzydlewski, 1966). Down hairs are darker, longer and more sparsely distributed than in adults. After about 1.5 months primary hairs fall out, and in their place are starting to grow secondary guard hairs. This process continues until approximately 5 months of age and ends with reaching so called first maturity of growing cover. This cover has about 80% of the adult animal hair density (Kopański, 1977). From 5 to 7.5 months lasts the second moulting, which ends with the second maturity of fur. The new generation of hair arises from existing hair follicles through the growth of the hair bulb matrix using already created sheath (Bielańska-Osuchowska, 2004). Density and other properties of this fur are identical to those of adult animals fur.

Tuft surfaces and distances between them depend on species, age and body part. The results of the present study are consistent with histological analysis conducted by Ptak (1966) whereby young nutria were characterized by a dense distribution of tufts (on average every 52.2 μm) which were small (29 250 μm²). Due to the increase of hair roots number, the surface increased to 98 733 μm² with age. The distribution became less frequent (156.7 μm). Tufts were observed rarely in the dorsal region, where the distance between them averaged 137.2 μm, while they were densely distributed in the abdominal region (average of 71 μm). A similar size of tufts (87 246 μm²) occurs in blue fox skin (Piórkowska and Natanek, 2007). Studies on young goats showed that with age, when skin is growing, density of pelage decreases because of increased distance between tufts (McDonald, 1985). Other studies confirmed increase of hair follicles groups diameter, because of increased number of primary and secondary hair follicle (Dong et al., 2010). The shape of bundles depends on cross-section height through skin (Stewart et al., 2013). In nutria skin the bundles are characterized by different shapes: from round, triangular, trapezoidal to diamond. At the base bundles are usually circular, but they change shape to ellipse or rectangle near sebaceous glands (Ptak, 1966). This observation is consistent with the results of our analysis where shape of bundles was variable, but mostly oval, rectangle or cuboid. Arranged to each other tufts form a checkerboard pattern, which was noticed also in the skin of young mice (Slee, 1962).

Number of down hairs in cluster and number of clusters in tuft is variable and depends on species. According to our studies nutria contain about 4–9 clusters in bundle, which does not change significantly with age. Histological studies on standard nutria pelts (Ptak, 1966) showed similar number of down hairs in cluster. It was found that on one guard hair occurs an average of 27.4 down hair. Mink coat studies showed about 21 (Natanek et al., 2001) to 26 (Kondo et al., 2004) down hairs in the cluster, which is comparable to the present results. Like in nutria pelage, bundles have different composition, there are bundles with guard hair or without. There are also single bundles (Kondo et al., 2000). Like in nutria, number of down hair in cluster increases with age from about 1.5 at 4 weeks of age to 22 at 30 weeks of age (Kondo and Nishiumi, 1991). The most common configuration in foxes are triads, i.e. tufts consisting of three clusters, one of which has a guard hair, the rest of them contain awn hairs around which are gathered down hairs (Maurel et al., 1986). Histological studies (Piórkowska and Natanek, 2007) showed the average number of clusters in a tuft to be 2.7 and the number of down hairs in tuft to be about 96. Chinchilla furs usually contain tufts with 1–2 guard hairs surrounded by numerous clusters of down hairs (Oznurlu et al., 2011). New Zealand rabbits have also compound hair follicles constituted of a central primary hair follicle and clusters of 2–4 down hairs (Oznurlu et al., 2009). These results differ from the present studies, which is probably the result of adaptation to different habitat between terrestrial mammals and semi-aquatic species like nutria.

Thickness of hairs depends on various factors. Differences in nutria pelt quality have been shown according to season (Głogowski and Majewska, 2009). Older individuals have thicker guard and down hairs in winter. While in the summer, younger individuals have thicker guard hair mainly on back and sides of the rump. Thickness of hair changes with age. Studies (Piórkowska et al., 1996) show that thickness of down hairs increases up to 6 months of age and after that stabilizes, whereas this feature of guard hairs is more varied. In the presented studies no increase of down hair thickness was noticed and the thickness was stabilized throughout the growing period. Studies on older nutrias (10–14 months old) (Ocetkiewicz et al., 1972) showed that the thinnest guard and down hairs were on belly and the thickest on the back. In adult nutria hair thickness is stabilized and does not change so rapidly like in young individuals, which was also confirmed in the present study in the case of guard hairs. According to the presented studies the average thickness of the down hair in nutria pelt is 18.5 µm and guard hair about 130 µm. Another semi-aquatic animal, sea otter, has thinner guard (44–106 µm) and down hair (7.6–11.9 µm), which is compensated by higher fur density (Williams et al., 1992). For comparison, common rat has also thinner down hair (11 µm) and guard hair (57 µm) (Demirel et al., 2014). In the present study morphometric analysis of nutria hair showed no differences from the standard mammalian hair structure (Morioka, 2005). Structure and size of hair follicle depend on cut level and stage of differentiation. The presence of certain layers and their thickness allows determining the height at which hair was cut (Stewart et al., 2013). The present study showed more than twice larger surface of hair near bulb than along the fiber. A similar correlation was noted in the skin of sheep (Dreyer et al., 1983). Average bulb diameter in these animals was about 6500–7200 mm.

Nutria coat characteristics differ significantly between guard and down hairs. The guard hair are rare, but much longer than down hair and they are mostly responsible for the appearance of fur. The hair on the back is much longer and darker than that on the stomach site (Kowalska et al., 2010). Hair length depends on age and body part and, although there are many others histological parameters, it gives also important practical information about hair coat development. The results obtained are consistent with other studies (Ocetkiewicz et al., 1972) where down hair length ranged from 9 to 18 mm and increased from head to tail direction. Similarly, guard hair length ranged from 27 mm in the ventral part to 54 mm in the back part. Height of hair also depends on variety (Cholewa et al., 2006). Greenland nutria has shorter guard hairs than other varieties like Sapphire blue, White or Standard. Underfur of Greenland and White nutria is lower than that of Sapphire Blue or Standard. But there are no differences between males and females. Another semi-aquatic species, the sea otter has almost two times shorter guard hair (8.2–26.9 mm) but length of underfur is similar (4.6–15.8 mm) (Williams et al., 1992). In comparison length of guard hair of terrestrial species raccoon dog measures from 4.6 to 9.4 cm and down hair is about 2.5–6.0 cm (Korhonen et al.,1984).

Summing up the results obtained it can be stated that the most beneficial results of coat quality were observed between 6 and 7 months of age. Most of the features such as bundles surface, amount of down hairs in cluster, thickness and length of guard hairs stabilizes and no longer improves with age. Moreover, other features such as distance between bundles or thickness and length of guard hair may deteriorate. These results lead us to conclude that the age of six-seven months is the optimal time for slaughter. Histological studies on morphology of nutria skin and development of hair follicles can be useful not only to determine the optimum date for slaughtering and skinning animals, but they could be also the basis for other researches including different methods of breeding, nutrition or administration of pelt and skin quality stimulants. It could also allow comparing nutria skin features with other species and appreciate the value of fur from this animal.

References

Bielańska-Osuchowska Z. (2004). Zarys organogenezy – różnicowanie komórek w narządach. PWN, Warszawa.

Brzozowski M. (1984). Wpływ terminu uboju na jakość okrywy włosowej. Hod. Drob. Inwen., 32, 10, 1.

Cholewa R., Pawliczaj-Maj K., Szwaczkowski T. (2006). Genetic and environmental effects on body weight and fur height in nutria (*Myocastor coypus* L.). EJPAU, 9, 2: 1–9.

Demirel D.S., Demirel R., Ketani M.A., Balcı K. (2014). Effects on performance, skin and liver histology of different clinoptilolite levels in rat diets. TURJAF, 3, 3: 133–141.

Dong B., Cui Z., Yin X.,Wang H., Wang S. (2010). Studies on histological characteristics of jining gray goat skins and hair follicle. J. Shandong Agricul. Univ., 2: 258–262.

Dreyer J., Rossouw E., Steyn M. (1983). The histology of the pre-natal follicle and hair fibre in four curl types of the Karakul sheep. S. Afr. J. Anim. Sci., 13: 180–191.

Galbraith H. (2010). Fundamental hair follicle biology and fine fibre production in animals. Animal, 4, 9: 1490–1509.

Głogowski R., Majewska M. (2009). Descriptive analysis of selected hair and pelt parameters of Greenland nutria (*Myocastor coypus* Mol.) fur coat in three age groups. Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies, 11, 41: 138–147.

Hanusová E., Mertin D., Lohi O., Süvegová K., Stepanok V. (2000). Relationship between the content of various elements in fur of nutria (*Myocastor coypus*). Scientifur, 24, 3: 193–196.

Ibe C.S., Salami S.O., Ajayi I.E. (2014). Trunk and paw pad skin morphology of the African giant pouched rat (*Cricetomys gambianus*, Waterhouse-1840). Eur. J. Anat., 18, 3: 175–182.

Kondo K., Nishiumi T. (1991). The pelage development in young mink (*Mustela vison*). J. Fac. Agr. Hokkaido Univ., 64, 4: 247–255.

Kondo K., Vanek M., Rasmussen P.V., Blomstedt L. (2000). The beauty of mink pelage observed with SEM. J. Fac. Agr. Hokkaido Univ., V7, 1: 1–8.

Kondo K., Ninomiya Y., Ischikawa H., Kato M., Fukunaga S., Hosaka A.K. (2004). Hair density and morphology of medulla in Mustelidae. Scientifur, 28, 3: 283–287.

Kopański R. (1977). Chów nutrii. PPWRiL, Warszawa, pp. 17–22.

Korhonen H., Harri M., Asikainen J. (1984). Moulting and seasonal variation in the raccoon dog. Act. Theriol., 29, 7: 77–88.

Kowalska D., Bielański P., Łapiński S. (2010). Nutrie – perspektywy hodowli. Wiad. Zoot., 48, 1: 39–45.

Lohi O., Thorhauge K., Rasmussen P. (1996). Sensory evaluation of fur quality and physical-mathematical measurements on mink pelts. Anim. Prod. Rev., Appl. Sci. Rep., 29: 103–108.

Maurel D., Coutant C., Boissin-Agasse L., Boissin J. (1986). Seasonal moulting patterns in three fur bearing mammals: the European badger (*Meles meles* L.), the red fox (*Vulpes vulpes* L.), and the mink (*Mustela vison*). A morphological and histological study. Can. J. Zool., 64, 8: 1757–1764.

McDonald B. (1985). Cashmere growth cycle and skin histology. Australian Cashmere Goat Society, Cashmere Goat, Note G1/1.

Meyer W. (2009). Hair follicles in domesticated manuals with comparison to laboratory animals and humans. In: Hair loss disorders in domestic animals. L. Mecklenburg, M. Linck, D.J. Tobin, (Eds.) Wiley-Blackwell, ss. 43–60.

Mobini B. (2012 a). Morphometry of the hairs in different regions of skin in adult Bakhtiari sheep. Middle-East J. Sci. Rer., 12, 5: 603–607.

Mobini B. (2012 b). Effect of age and sex on fiber and follicle characteristic of an Iranian native sheep. SJVS, 10, 1: 1–4.

Morioka K. (2005). Hair Follicle: Differentiation Under the Electron Microscope: An Atlas. Springer, Tokyo.

Natanek A., Wojtysiak D., Barabasz B., Langenfeld M. (2001). Badania nad gęstością okrywy włosowej u norek z uwzględnieniem obrazu histologicznego skóry. Rocz. Nauk. Zoot., Supl., 12: 209–214.

Ocetkiewicz J., Rychlicki Z., Kawińska J., Niedźwiadek S., Wrona J. (1972). Wyniki badań laboratoryjnych futerek nutrii pochodzących ze zwierząt ubijanych w wieku 10, 12 i 14 miesięcy życia. Rocz. Nauk. Rol., B-94-1: 67–79.

Oznurlu Y., Sur E., Telatar T., Ozparlak H. (2009). Comparative skin histology of the White New Zealand and Angora rabbits: Histometrical and immunohistochemical evaluations. J. Anim. Vet. Adv., 8, 9: 1694–1701.

Oznurlu Y., Celik I., Sur E., Ozaydin T. (2011). Histological examination of the skin and AgNOR parameters of matrix pili cells in the chinchilla. Eurasian J. Vet. Sci., 27, 1: 39–43.

Piórkowska M., Kowalska D., Niedźwiadek S. (1996). Badania wartości futrzarskiej skór w zależności od wieku nutrii przy uboju. Anim. Prod. Rev., Appl. Sci. Rep., 29: 175–179.

Piórkowska M., Natanek A. (2007). Ocena jakości okrywy włosowej populacji lisa polarnego z uwzględnieniem obrazu histologicznego skóry. Rocz. Nauk. PTZ, 3, 4: 331–337.

Ptak W. (1965). Obraz budowy histologicznej skóry nutrii (*Myocastor coypus* Mol.), część I, Acta Agr. Silv., ser. Silv., 6: 33–59.

Ptak W. (1966). Obraz budowy histologicznej skóry nutrii (*Myocastor coypus* Mol.), część II, Acta Agr. Silv., ser. Silv., 6: 65–91.

Riis B. (1998). Biochemistry and skin quality – tools and perspectives. DIAS Internal Report, 111: 23–28.

Schneider M., Schmidt-Ulrich R., Paus R. (2009). The hair follicle as a dynamic miniorgan. Current Biol.,19, 3: 132–142.

Sick S., Reinker S., Timmer J., Schlake T. (2006). WNT and DKK determine hair follicle spacing through a reaction-diffusion mechanism. Science, 314: 1447–1450.

Skrzydlewski A. (1966). Postnatalny rozwój nutrii. Roczn. Wyż. Szk. Roln. w Poznaniu, 32, 8: 193–211.

Slee J. (1962). Developmental morphology of the skin and hair follicles in normal and in 'ragged' mice. J. Embryol. Exp. Morph., 10, 4: 507–529.

Stewart E., Ajao M.S., Ihunwo A.O. (2013). Histology and ultrastructure of transitional changes in skin morphology in the juvenile and adult four-striped mouse (*Rhabdomys pumilio*). Sci. World J., (259680): 2356–6140.

Wang B., Wang C., An T. (2007). Histological observation of hair follicles during early development in mice. Acta Laboratorium Animalis Scientia Sinica, 6: 413–415.

Williams T., Allen D., Groff J., Glass R. (1992). An analysis of California sea otter (*Enhydra lutris*) pelage and integument. Marine Mammal Science, 8, 1: 1–18.

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MARTA NABOŻNY, ANNA NATANEK, MAŁGORZATA PIÓRKOWSKA

Wpływ wieku na obraz histologiczny okrywy włosowej nutrii grenlandzkiej

STRESZCZENIE

Celem pracy była ocena rozwoju okrywy włosowej nutrii odmiany grenlandzkiej z uwzględnieniem obrazu histologicznego mieszków włosowych. Próbki skór do analizy histologicznej zostały pobrane ze środkowej partii ciała grzbietu i brzucha począwszy od 3. do 9. miesiąca życia. Zaobserwowano, że powierzchnia kępek, ilość pęczków w kępce i ilość włosów puchowych w kępce wzrastały z wiekiem. Zaobserwowano również wzrost odległości między kępkami w kolejnych miesiącach życia. Długość i grubość włosów puchowych i okrywowych oraz powierzchnia rdzenia wzrastały, natomiast powierzchnia kory malała wraz z wiekiem. Długość włosów, powierzchnia kępek i ilość włosów puchowych w kępce zależały od partii topograficznej ciała i były wyższe w części grzbietowej. Okolica grzbietowa charakteryzowała się również grubszymi włosami pokrywowymi. Podsumowując uzyskane wyniki można stwierdzić, że najbardziej korzystne parametry miała okrywa włosowa między 6–7 miesiącem życia nutrii. Większość badanych parametrów, takich jak powierzchnia kępek, ilość włosów puchowych w kępce, grubość i długość włosów pokrywowych, osiągała w tym czasie optymalne wartości. Ponadto, inne cechy, takie jak odległości między kępkami lub grubość i długość włosów przewodnich po tym okresie ulegały pogorszeniu. Wyniki te są podstawą do uznania, że wiek 6–7 miesięcy jest optymalnym czasem uboju. Badania histologiczne dotyczące rozwoju okrywy włosowej nutrii mogą być przydatne nie tylko w celu określenia najbardziej optymalnego terminu uboju tych zwierząt, ale mogą być również podstawą do innych badań dotyczących różnych metod hodowli, żywienia lub wpływu różnych substancji na wzrost okrywy włosowej.