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THE CHARACTERISTICS OF COAT COLOR OF SANDOMIERSKA GOATS

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ABSTRACT

The Sandomierska goat is one of three native breeds of goats living in Poland. A characteristic feature of Sandomierska goats is their colorful coat. Currently, four types of coat color are distinguished: gray-piebald, black-piebald, brown-piebald and three-colored. The color of the skin and fur is one of the forms of adaptation to relevant climate, because the thermoregulatory reaction varies depending on the color of the coat. Therefore, the aim of the study is to analyze the frequency of types of coat color in Sandomierska goats, and the general characterization of goat hair. Both sexes of the Sandomierska goat are dominated by black-piebald color. The least common color is brown-piebald. In turn, the three-colored coat was identified only in females registered in breed registry. The hair analyzed showed the presence of an intermittent, fragmented and a spongy medulla. Hair scale pattern are regular and unregular wave with rippled scales margin in Sandomierska goats.

Key words: local breed of goats, Sandomierska breed, coat color, hair morphology

INTRODUCTION

Goats are one of the earliest domesticated animals and have been associated with humans for at least 10,000 years. These animals are an adaptation of the wild ibex (*Capra aegagrus*), which occurs in western Asia [Amills et al. 2017]. During the Neolithic period, farmers in the Middle East and Western Asia raised small herds of ibex for meat and milk. Goats are one of the most versatile animals. They provide: meat, milk, fiber, leather, animal traction and manure as a fertilizer [Sejian et al. 2021]. Goat farming has a number of environmental benefits. These animals protect natural wildlife habitats, prevent the spread of invasive plants, and encourage the growth of shrubs and trees through careful grazing. Unlike many other farm animal species, goats do not need as much water to survive compare to others [Kaliber et al. 2016, Sejian et al. 2021]. There are over 1,000 breeds of goats on our planet [FAO 2013]. Goats are characterized by a variety of structures, types of coat and types of performance. Due to their adaptability, they are scattered all over the world. These animals inhabit every continent except Antarctica and live in a variety of environments, including demanding ones, ranging from humid tropical rainforests, through hot desert regions, to colder and high-altitude regions. They have features that enable the conversion of feed into milk and meat even in extreme climatic conditions [Silanikove 2000, Sejian et al. 2021]. The domestication process influenced the transformation of the morphological, physiological and behavioral characteristics of the animal under the impact on environmental factors and human selection. The processes of goat domestication and dispersal in the environment have induced changes in many morphological characters, driven by targeted selection, genetic drift, isolation and the founder effect, consequently giving rise to a large variety of shapes and a remarkable range of colors [Amills et al. 2017]. Coat color was considered the main feature influencing the development of new breeds, and ultimately leading to the creation of closed populations [Arenas-Báez et al. 2023].

The Sandomierska breed is one of three native breeds of goats maintainedin Poland. Animals of this breed come from the Vistula Lowland, the area where the San River flows into the Vistula, near the city of Sandomierz (50°40′57″N; 21°44′56″E). A characteristic feature of

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Sandomierska goats is their colorful coat. Initially, it was described as a white animal with three-colored patches: gray, black or yellow-brown. Currently, four types of coat color are distinguished: gray-piebald, black-piebald, brown-piebald and three-colored (Fig. 1.A-D) [Sikora 2023]. The conformation of Sandomierska goats is characterized by harmonious body structure. All animals are horned and have beards, which are more abundant in males. According to Szymanowska et al. [2017], the average height at the withers of adult female goats is approximately 62 cm, and that of male goats is 59–74 cm. Both female and male goats have a stronger build compared to the kazimierzowska goats. Moreover, this breed is characterized by high fecundity and fertility, low nutritional requirements and high resistance to diseases [Sikora 2023].

According to FAO [2013], the global strategy for the conservation of genetic resources includes: identifying and understanding the unique genetic resources of farm animals in regions and developing the appropriate use of this diversity, which constitutes an extremely valuable genetic reservoir. Goats exploited in extensive systems are native (local) animals. They are characterized by a heterogeneous phenotype in which skin and fur color show remarkable variability. This is one of the forms of adaptation to relevant climate, because the thermoregulatory reaction varies depending on the color of the coat. Therefore, there is a need to understand the basis of local adaptation related to the color of goats. Therefore, the aim of the study is to analyze the frequency of types of coat color in Sandomierska goats and the characterization of goat hair.

A B C D

Fig. 1. Types of coat color of Sandomierska goats: A, three-colored, B, black-piebald, C, brown-piebald, D, grey-piebald (photo Zbigniew Kołodziej)

MATERIAL AND METHODS

The analysis of the coat color of Sandomierska goats was collected on the basis of data from breed registry of the University of Life Sciences in Lublin in 2022–2023. The animals entered in the breed registry are localized in eight herds and are included to performance control conducted by the University of Life Sciences in Lublin. The number of Sandomierska goats in breed registry is changing dynamically, therefore the analysis included data in current day (June 30, 2023), including information on the color of 222 female goats and 33 bucks. These animals came from herds located in the following voivodeships: Lublin, Masovian, Lesser Poland and Lower Silesia (Fig. 2). Hair for analysis was collected from 32 adult females (8 in each coat color) and 9 males (3 in each coat color). Microscopic analysis of the hair was performed using a Leica DM750 microscope (Leica Microsystems, Switzerland) with a polarizer (eyepiece: 10×/22mm FOV) using objective magnifications of 10×, 20× and 40×. For each sample 3 microscopic analysis were done.

RESULTS AND DISCUSSION

The outer surface of the animal's body (skin and fur) is important for adapting to the environment [Mota-Rojas et al. 2021]. It is the first protective barrier against pathogens and also against environmental conditions. The coat may vary in color, length and hair thickness. Both sexes of the Sandomierska goat are dominated by black-piebald color [61.7% (n = 137) in female goats and 54.5% (n = 18) in bucks] (Fig. 3 and 4). The least common color is brown-piebald [7.2% (n = 16) in female goats and 12% (n = 4) in bucks]. In turn, the three-colored coat was identified only in female goats registered in breed registry (n = 36). A characteristic feature of the Sandomierska breed is the multi-colored coat of the animals compared to the other two Polish native breeds of goats – uniform-light coat in karpacka goats or uniform-dark coat in kazimierzowska goats [Sikora 2023]. In mammals, color depends on the synthesis and distribution of melanin in the hair and epidermis. The key enzyme responsible for the production of melanin is tyrosinase. In turn, the activity of this enzyme is regulated by melanocyte-stimulating hormone (MSH) using positive feedback. Moreover, the level of the tyrosinase enzyme affects the form of melanin secreted, which determines the pattern of mammalian fur. At low and high level of the tyrosinase enzyme, pheomelanin (red/yellow pigment) and eumelanin (black/brown pigment) are being produced respectively [Arenas-Báez et al. 2023]. These pigments are produced in melanocytes, where complex regulation of melanin synthesis occurs. This process is determined by the gene expression profile and epigenetic mechanisms. Although their influence on fur color has not yet been well understood, an important role in determining the fur color phenotype is attributed to the Agouti gene (ASP), which participates in the qualitative and quantitative production of pigment in melanocytes. High ASP expression stimulates the synthesis of pheomelanin while inhibiting the production of eumelanin. So

Fig. 2. Location and number of Sandomierska goats herds

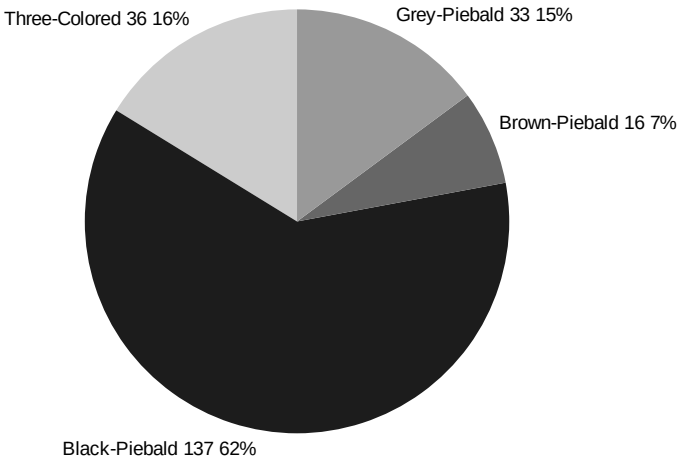

Fig. 3. Freguency of coat color in Sandomierska female goats

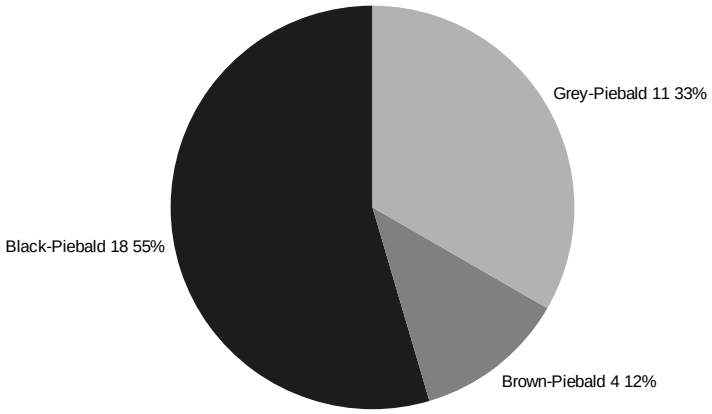

Fig. 4. Freguency of coat color in Sandomierska goat bucks

far, genetic research has identified about 80 genes responsible for goat fur color [Li et al. 2017]. Analyzes have shown that there is no single locus explaining the color discrepancy and the phenotype is the response of many loci with distinct pleiotropy, epistasis, and other effects related to environmental factors [E et al. 2016].

So far, it has been shown that coat color can be considered as genetic factor of adaptation to various climatic conditions, as differences in thermoregulation are visible in animals with dark and light coats. This effect is related to the greater absorption coefficient of solar radiation by black fur and consequently better adaptation of dark-colored goats to low temperatures. Therefore, the black pigment present in dark fur allows them to heat up faster compared to light-colored goats [Chokoe et al. 2020]. Similarly, Ferreira et al. [2021] reported that during the rainy season, black coat color allows goats to absorb more solar energy during cool mornings and thus reduce heat loss. In turn, light fur reflects solar radiation better, and therefore is characterized by lower heat absorption, maintaining a lower skin surface temperature, which protects the animal from excessive overheating [Krawiec et al. 2020]. However, skin penetration depends on the structure of the coat and its color. For this reason, Castro Lima et al. [2020] discussed the physiological reactions of two breeds of goats with different colors and showed greater protection against solar radiation in tropical climates with colored fur and darker skin color compared to white fur but with thicker hair. Some reports indicate that coat color significantly affects physiological indicators of heat tolerance (rectal temperature (RT), respiratory rate (RR), heart rate, caloric stress index and some hematological parameters, such as aldosterone concentration). These suggests that goats of different colors

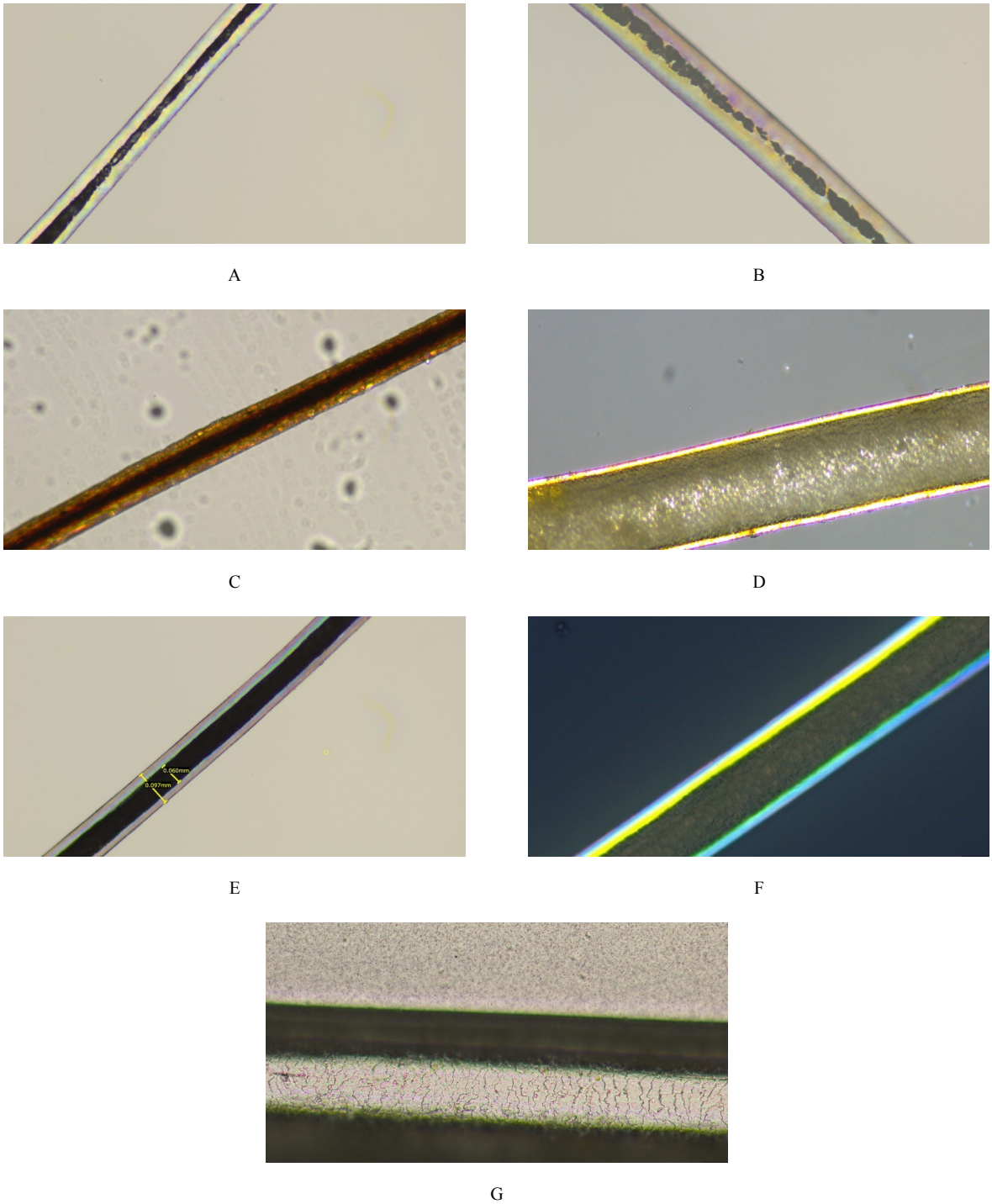

Fig. 5. Morphology of the core (A–F) and scales (G) of the hair of Sandomierska goats; A, intermittent core (white hair), B, fragmentary core (white hair), C, continuous core with irregular edges (black hair), D, spongy core (white hair), E, continuous core with regular edges and core index measurement (white hair), F, hair without visible core (dark hair), G, regular wave scale

have different thermoregulatory abilities [Adedeji 2012, Aleena et al. 2020]. The criterion of tolerance and adaptation of animals is determined by the transfer of heat to the skin through the dilation of arterioles to the limbs, ears and muzzle, which allows for an increase in peripheral blood flow and facilitates heat transfer [Fonseca et al. 2016].Evidence for the above has been reported [Aleena

et al. 2020, Araújo et al. 2020,] observing a lower frequency of urination in animals with dark fur.

Other study indicated that animals exposed to solar radiation with dark fur have higher RR, pulse rate (PR), sweat rate, and higher skin and RT. The study conducted in India in Sirohi goats exposed to heat stress showed that RR, PR and RT were higher in black-furred goats and then decreased in dark brown, light brown and white goats, respectively [Acharya et al. 1995]. Therefore, black fur appears to be unfavorable for goats living in hot conditions, as they are exposed to a greater heat load than light-colored goats, especially if exposed to solar radiation. Adaptation to environmental conditions is also related to the insulating value of fur, which may be influenced by the color, density and structure of the hair [Mota-Rojas et al. 2021]. In animals we distinguish guard hairs and undercoat. Guard hairs are the longest and thickest hairs in mammals' fur, forming the outer layer. They narrow towards the end and protect the lining against moisture. They are often waterproof and stick out above the rest of the fur. Guard hairs can vary in morphology depending on where they grow in most mammals. The undercoat is the fine, downy hair closest to the skin. The hair is short and often crimped, which makes it very effective at trapping air and thus thermally insulating the animal.

The histological structure of hair is specific to the species and includes: the pattern of cuticle scales, the structure of the medulla (continuous or interrupted) and the shape of the hair's cross-section [Roman et al. 2016]. The medulla is the innermost layer of the hair shaft. It consists of a number of discrete cells or an amorphous, spongy mass filled with air. The medulla in the hair is usually continuous and has a very regular structure (Fig. 5C, 3E). In animals, it covers an area greater than half of the total diameter of the hair shaft, compared to human hair, where this figure is usually less than one third [De Marinis and Asprea 2006, Knecht 2012]. When the medulla is not uniform and does not extend along the entire length of the hair, it is said to be fragmentary or interrupted and then is interrupted by cortical material (Fig. 5A-B). The medulla is classified as absent where it is not visible and the cortex is continuous throughout the hair (Fig. 5F). In contrast, continuous, uninterrupted, amorphous core looks like a continuous ribbon-like tube. In the microscopic image, it appears darkened, without structural details (Fig. 5E), or it may take a spongy form, without visible cells in the hair (Fig. 5D). The core is filled with a vacuum, which increases thermal insulation in animals [Knecht 2012].

Thicker medullary fibers occur in animals living in conditions characterized by a much lower average annual temperature [Radzik-Rant et al. 2014]. Moreover, hair with a thicker core is stiffer and more brittle, while hair elasticity is related to a larger amount of the cortex [Roman et al. 2016]. In this study, hair samples were collected in early summer (end of June in 2023 – average temperature in June in Poland is 17.5°C – data from IMWM), when temperatures in Poland are high) and the hair coat is replaced seasonally.

The hair cuticle it is the outer layer of the hair, originates from a single-layered epithelium and is made up of a large number of overlapping transparent scales of keratin. All the scales present along the hair shaft, i.e. that part of the hair outside of the skin, have a specific contour and are arranged in a more or less typical pattern that can be used for the identification of mammalian groups and/or species [Meyer et al. 2002]. Animals have crown-like and spinuouus scales, while humans have imbricate type -flattened scale patterns. The cuticles have a protective effect, preventing damage to the internal structure of the hair and controlling the water content in the hair. In Sandomierska goats hair scale pattern as regular and unregular wave with rippled scale margin were demonstrated [De Marinis and Asprea 2006, Ahmed et al. 2018].

Hair follicles also play a key role in thermoregulation. Their vascularization comes from the deep vascular plexus of the dermis [Mota-Rojas et al. 2021]. Regardless of whether animals are exposed to low or high temperatures, the musculature controls the position of the hair, increasing or decreasing its insulating capacity. Relaxation occurs in a hot environment to condition the hair and reduce the insulating layer between the skin and hair. This reaction allows heat to be lost, thereby lowering body temperature. However, under the influence of cold, piloerection occurs, i.e. the hair ruffling reaction, during which the contraction of the hair muscle increases the fluffiness of the hair, and as a result, the amount of air accumulated between the skin and the hair increases.

CONCLUSIONS

Both sexes of the Sandomierska goat are dominated by black-piebald coat color. The least common coat color is brown-piebald. In turn, the three-colored coat was identified only in females registered in breed registry. The hair analyzed showed the presence of an intermittent, fragmented and a spongy medulla. Continuous cores took forms with regular and irregular edges. Hairs without a visible core were also observed. In Sandomierska goats hair scale pattern as regular and unregular wave with rippled scale margin were demonstrated. In order to analyze the hair coat more precisely, a comparative analysis of the winter and summer coat should be carried out.

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CHARAKTERYSTYKA UMASZCZENIA KÓZ SANDOMIERSKICH

STRESZCZENIE

Rasa sandomierska jest jedną z trzech rodzimych ras kóz występujących w Polsce. Cechą charakterystyczną kóz sandomierskich jest ich kolorowa sierść. Obecnie wyróżnia się cztery rodzaje umaszczenia: szaro-srokaty, czarno-srokaty, brązowo-srokaty i trójbarwny. Kolor skóry i sierści jest jedną z form przystosowania się do danego klimatu, ponieważ reakcja termoregulacyjna zmienia się w zależności od koloru sierści. Dlatego celem pracy była analiza frekwencji występowania typów umaszczenia kóz sandomierskich oraz ogólna charakterystyka sierści kóz. U obu płci kozy sandomierskiej dominuje umaszczenie czarno-srokate. Najmniej powszechny kolor to brązowo-srokaty. Z kolei trójbarwną sierść zidentyfikowano jedynie u samic zarejestrowanych w księgach hodowlanych. Analizowane włosy wykazały obecność przerywanego, fragmentarycznego i gąbczastego rdzenia. U kóz sandomierskich wzór łusek włosa to regularne i nieregularne fale z pomarszczonym brzegiem.

Słowa kluczowe: rodzima rasa kóz, rasa Sandomierska, kolor umaszczenia, morfologia włosa

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