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PROXIMATE HAIR ANALYSIS IN MALE AND FEMALE DROMEDARY AND BACTRIAN CAMELS

Katarzyna Ząbek, Sebastian Wójcik, Jerzy Dzida, Jan Miciński

Department of Sheep and Goat Breeding, Faculty of Animal Bioengineering, University of Warmia and Mazury in Olsztyn, ul. Oczapowskiego 5, 10-719 Olsztyn, Poland

ABSTRACT

The aim of this study was to analyze the diameter of hair fibers collected from camels kept in Poland, and to determine differences in fiber structure between camel sexes and species. Hair samples were collected for analysis from 28 adult camels divided into groups based on sex (18 females and 10 males) and species (18 dromedary camels and 10 Bactrian camels). The samples were collected in May–July 2020, at the level of the last rib. The diameter of 42,000 fibers was measured by the modified projection microscope method. The fibers were classified into three categories: non-medullated fibers, fibers with interrupted medulla and fibers with continuous medulla. The study demonstrated that the hair fibers of camels kept in Poland had a mean diameter of 20.23 µm. Non-medullated fibers had the smallest diameter (17.32 µm). The smallest significant ($P \leq 0.05$) difference in fiber diameter between males and females was noted in non-medullated fibers. Mean fiber diameter was higher in males than in females, especially in guard hair. No differences in fiber medulla diameter were found between camel sexes or species. Hair from Bactrian camels was thinner, and the proportion of non-medullated fibers was more than 50% higher than in dromedaries.

Key words: hair, fiber diameter, dromedary camels, Bactrian camels, non-medullated fibers, medullated fibers

INTRODUCTION

Camels have played an important role since the dawn of human civilization as a source of milk, wool, meat, fuel, and a means of transport for carrying passengers and goods. Camels have fueled the development of many civilizations, and they have enabled humans to explore distant regions of the world.

There are two main surviving species of camel: the one-humped dromedary (*Camelus dromader*) that is found throughout Africa, Arabia, the Middle East and other hot and arid regions of Asia and the two-humped Bactrian camel (*Camelus bactrianus*) that lives mainly in Mongolia and north China in areas bordering the arid and cold Gobi Desert. Bactrian camels are used to transport people and goods; they are occasionally used for sports activities, and they are a source of fiber for textile production [Khomeiri and Yam 2015].

The fibers obtained from the Bactrian camel are characterized by superior quality, which is why most textiles and clothing items are made from the wool of two-humped camels [Hasi et al. 2020]. The average wool yield of Bactrian camels is 2.6–8.3 kg and depends on age and gender [Khomeiri and Yam 2015]. China and Mongolia are the world's leading suppliers of camel wool. The Bactrian camel occupies a narrow habitat range, and it is found mainly in arid and semi-arid regions of Mongolia, China, Kazakhstan, and Kyrgyzstan. Camel wool of lower quality is also produced in Tibet, Afghanistan, Iran, Russia, New Zealand, and Australia [Hasi et al. 2020].

The Food and Agriculture Organization reports, that Camels are reared in 46 countries around the world, and their global population is estimated at 35.5 million (www.fao.org). In the past, camels were used mainly as pack animals to transport heavy goods and passengers; they were an important source of wool, milk, meat and hide, and they were also raised for recreational purposes [Nelson et al. 2015, Faye 2022].

micinsk@uwm.edu.pl

In Poland, camels are kept mainly in zoos and amusement parks. These exotic animals attract many viewers due to their intriguing appearance and behavior [Faye 2014]. However, camels are also increasingly often encountered in agritourism farms in rural areas. Several camel dairy farms have opened in Poland in recent years, and one of such projects was launched in Sanie in the region of Lower Silesia.

Camels have evolved in the harsh desert environment, and they are very well adapted to extreme climatic conditions due to their protective hair coat. Camel wool is renowned for its flexibility and durability, and garments and other products made of camel wool are characterized by high quality and wear-resistance. Camel wool has excellent insulating properties, and according to some breeders, it is much warmer than sheep wool. Camel wool is characterized by thin fibers with a diameter of around 20–23 µm, which is comparable with merino wool [Kuźnicka and Grondkowska 2014]. When the camels moult, the hair can be obtained by combing, shearing (done more commonly today) and collecting of sched hair Hunter [2020].

Camel wool is considered to be the most durable type of wool in the world, and its unique structure contributes to softness that meets the needs of the most demanding customers. Camel wool can be combined with other animal and plant fibers during the production process. Camel wool has a unique color, and it is rarely dyed [Khem et al. 2011]. Typical camel yarn has a golden tan color with shades of red [Karthik et al. 2015]. The color of camel wool is determined by species, climate, and individual traits. Camels living in hot regions of Asia and Africa have light brown fur, whereas dark brown color is more predominant in colder parts of the world [Kazakov et al. 2021].

The camel hair coat is heterogeneous, and it includes long, coarse, as well as soft fibers [Hasi et al. 2020]. Several types of fibers, differing in structure and properties, have been identified in the camel hair coat. Fibers with the most desirable diameter account for around 50% of the hair coat, and they are even twice as expensive as thicker fibers on international markets [Khomeiri and Yam 2015]. Camel hair is irregular, and it does not have a clearly braided or clustered structure. The fiber bundle is centered around a coarse hair, and it is surrounded by several or even a dozen soft hairs with varied thickness. The camel hair coat is composed of an upper and a lower layer. The upper layer consists of sparse, upright, and thick medullated fibers, whereas the upper layer contains soft and thick fibers [Hasi et al. 2020].

According to Kerven et al. [2002], the camel hair coat consists mainly of fine fibers (75–80%) and smaller proportions of middle-quality fibers (15–20%) and coarse fibers (5–10%). In the cited study, the average fiber diameter was determined at 16–20 µm in fine fibers, 25–30 µm in middle fibers, and 31–50 µm in coarse fibers. Fine fibers had a length of 3–5 cm, middle fibers, 4–6 cm, and coarse fibers, 8–10 cm. In the work of Kuźnicka and Grondkowska [2014], coarse and fine camel hair differed in the proportions of fine down (14.4–23.6 µm) and cashmere. Thick hair contained 66.5–84.7% and thin fine hair contained 86.0–94.4% of soft down. Camel hair can be divided into two fractions. The first fraction consists of thick hair fibers with interrupted or continuous medulla. The second fraction consists of thin non-medullated or medullated hair fibers.

The aim of this study was to analyze the diameter of hair fibers collected from camels kept in Poland, and to determine differences in fiber structure between camel sexes and species.

MATERIAL AND METHODS

Camel hair fibers were subjected to analyses. Hair samples were collected from 28 adult camels, including 18 females and 10 males, kept in zoological gardens, agritourism farms and breeding farms in Poland. A total of 18 dromedary camels and 10 Bactrian camels were examined (the number of camels of each species was not equivalent to the number of males and females). The average age of the animals was 7.6 years. Hair samples were collected in May–July 2020, at the level of the last rib, midway between the dorsal median line and the ventral median line. Hair samples were analyzed to determine:

- proportions of fiber fractions,
- fiber diameter,
- medullation percentage.

The diameter of 42,000 fibers was measured by the modified projection microscope method (ISO 2015). Since fiber fractions were difficult to separate, 500 fibers per sample were measured in three replicates. Hair fibers were divided into fractions based on differences in their diameter and length, and the proportion of each fraction was expressed as a percentage. Microscopic specimens were prepared by placing fiber segments (approx. 1 mm long) on the slide in a drop of paraffin oil. Fibers were distributed evenly over the surface of the slide with the use of a needle, and cover glass was placed over the specimen. The specimens were examined under the Olympus CX41 phase contrast microscope equipped with an Artcam 500MI camera, at 20x magnification. Fiber diameter was obtained in the Quick Photo Camera program. The fibers were classified into three categories:

- non-medullated fibers (Fig. 1),
- fibers with interrupted medulla (Fig. 2),
- fibers with continuous medulla (Fig. 3).

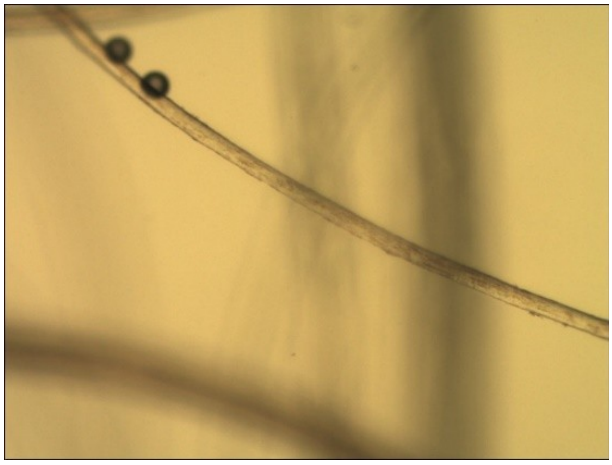

Fig. 1. A non-medullated fiber (photo K. Ząbek)

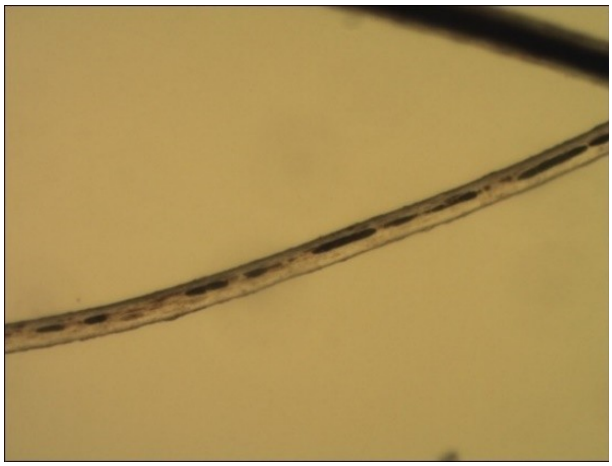

Fig. 2. A fiber with interrupted medulla (photo K. Ząbek)

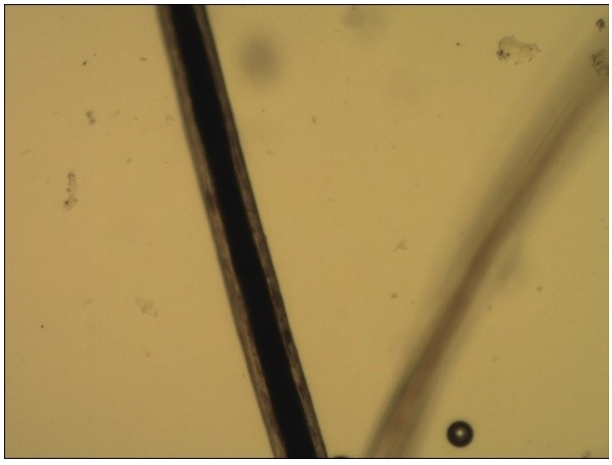

Fig. 3. A fiber with continuous medulla (photo K. Ząbek)

The statistical analysis was performed using Statistica ver. 13.0 software [StatSoft 2020]. The normality of distribution was checked by the Shapiro-Wilk test. The results were processed statistically by one-way analysis of variance (ANOVA), and the significance of differences between groups was determined by Tukey's test at $P \leq 0.01$ and $P \leq 0.05$. The differences among camel sex or species were estimated using the following model:

$$Y_{ij} = \mu + Y_i + e_{ij}$$

where:

Y_{ij} – observed level of dependent variable,
μ – is the overall mean,
Y_i – fixed effect of camel sex or species: $Y_i = \mu_i - \mu$, where μ_i – mean for the i-th group,
e_{ij} – random residual error.

RESULTS AND DISCUSSION

A total of 42,000 camel hair fibers were analyzed. Their mean diameter was 20.23 µm, ranging from 5 to 117 µm. The range of values is wide because hair samples included both soft down and protective guard hair. Fibers forming the hair coat represented two fractions: long and coarse fibers of the outercoat, and short and fine fibers of the undercoat. The undercoat predominated in all samples. Camel wool can be divided into four classes, based on its quality, i.e., hair softness and length, and the proportions of different fiber types (down, junction and medullated fibers). Class I includes fleece wool that consists mainly of down and junction hair, with a small amount of guard hair. In comparison with Class I, Class II comprises coarser wool, less down, and coarser junction hair. In Class III, wool consists of coarse hair with a small amount of down. Class IV includes wool waste [Alibayev et al. 2020]. In this study, camel hair fibers were divided into three categories, and their number and mean diameter are presented in Table 1.

An analysis of fiber categories revealed that non-medullated fibers accounted for 73.89% of all fibers, and their number was 31,032. They predominated in the analyzed samples. The mean diameter of these fibers was 17.32 µm. Wear comfort, defined as the percentage of hair with a diameter exceeding 30 µm in the coat, is an important factor affecting the perceptions of consumers wearing wool garments [Sacchero 2005]. In the present study, the proportion of medullated fibers was low at 12.85%, and their mean diameter was 34.57 µm (Fig. 4).

An attempt was also made to determine medulla diameter in fibers with continuous medulla. It was found that it ranged from 4 to 104 µm, and its mean value was 16.82 µm. No significant differences in fiber medulla diameter were found between camel sexes or species (Fig. 5).

The analyzed hair fibers were divided into two groups based on camel sex. 27,000 fibers were collected from females, and their mean diameter was 20.21 µm. 15,000

fibers were collected from males, and their mean diameter was 20.26 µm. Samples collected from females contained 70.18% non-medullated fibers with a mean diameter of 17.10 µm. Samples collected from males contained 80.56% non-medullated fibers with a mean diameter of 17.67 µm. The differences between group means were significant at $P \leq 0.05$ (Table 2). The number of non-medullated fibers was 10.4% higher in males than in females. According to Kazakov et al. [2021], the number of down fibers is higher in males than in females.

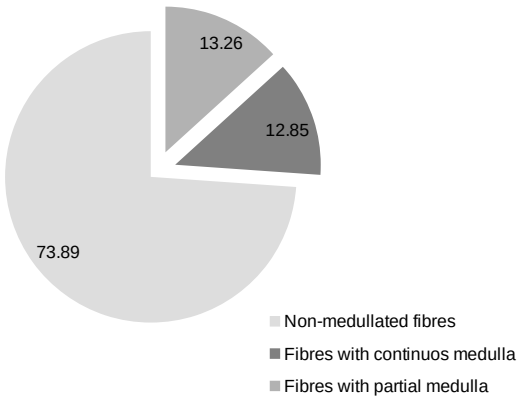

Fig. 4. Proportions of different types of camel hair fibers, %

Fibers with interrupted medulla were encountered least frequently in the microscopic analysis of hair samples. The number and mean diameter of fibers with interrupted medulla were 5571 and 22.54 µm, respectively. In females, their percentage content of fibers was 14.34, and mean diameter – 21.48 µm. In males, the respective values were 11.32% and 24.95 µm. The differences between sexes were highly significant (Table 2).

Fibers with continuous medulla were 5397, and mean diameter – 34.57 µm. In females, percentage content of fibers was 15.48 and mean diameter – 33.15 µm, for males it was 8.12, and 39.45 µm, respectively. The differences between sexes were significant at $P \leq 0.01$.

An analysis of hair fiber diameter in male and female camels did not reveal significant differences. Mean fiber diameter was 16.80 µm in females, and 16.92 µm in males. The number of medullated fibers was by 2979 higher in females than in males (Fig. 5).

In a study conducted by Kuźnicka and Grondkowska [2014], the mean fiber diameter was 40.26 µm, and the hair structure differed from that observed in our experiment. Specifically, continuous medullated fibers accounted for 78.39% of all fibers, fibers with interrupted medulla comprised 16.91%, and non-medullated fibers represented 4.71%. These differences could result from the fact that the cited study investigated only male one-humped camels kept in the Tunisian Sahara region. The presence of medullae in hair fibers is one of the adaptations to high daily temperature fluctuations [Kuźnicka and Grondkowska 2014]. Somewhat lower diameters of fibers were reported by Liu et al. [2018] and Harizi et al. [2007], at 17.9 and 17.0 µm, respectively. These lower values could result from different management and feeding conditions of the examined animals. The present findings are comparable with those reported by McGregor [2013], and Salehi and Gharahdaghi [2010], which ranged from 12.6 to 21.2 µm and from 16.8 to 39.2 µm, respectively.

In a study by Hunter [2020], the diameter of down fibers was found to range from 16 to 20 µm, while intermediate fibers had a diameter range of 20 to 29 µm. Guard hair, on the other hand, exhibited a much wider diame-

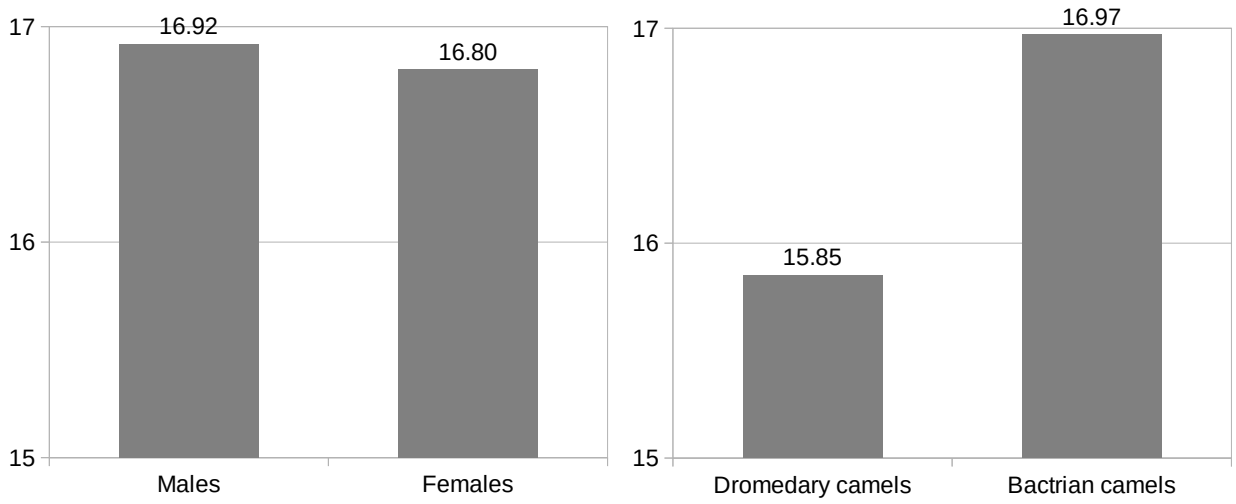

Fig. 5. Hair fiber medulla diameter in male and female dromedary and Bactrian camels, µm

Table 1. Classification and mean diameter of the analyzed camel hair fibers (μm)

Fiber type	Total		
	n	$\bar{x}$	SE
– non-medullated fibers	31032	17.32^{A}	5.31
– fibers with interrupted medulla	5571	22.54^{B}	8.81
– medullated fibers	5397	34.57^{D}	14.76
Total/mean	42000	20.23	9.62

Means in the same column with the different superscripts differ significantly at A, B – $P \leq 0.01$.

Table 2. Mean hair fiber diameter in male and female camels, μm

Fiber type	Group							
	female ♀				male ♂			
	n	$\bar{x}$	%	SD	n	$\bar{x}$	%	SD
– non-medullated fibers	18948	17.10^{b}	70.18	5.12	12084	17.67^{a}	80.56	5.59
– fibers with interrupted medulla	3873	21.48^{B}	14.34	8.50	1698	24.95^{A}	11.32	9.02
– medullated fibers	4179	33.15^{B}	15.48	14.83	1218	39.45^{A}	8.12	13.40
Total/mean	27000	20.21	100	9.78	15000	20.26	100	9.31

Means in the same line with the different superscripts differ significantly: A, B at $P \leq 0.01$, a, b at $P \leq 0.05$; n – number of fibers; SD – standard deviation.

Table 3. Mean hair fiber diameter in dromedary and Bactrian camels (μm)

Fiber type	Group							
	Bactrian camels				Dromedary camels			
	N	$\bar{x}$	%	SD	n	$\bar{x}$	%	SD
– non-medullated fibers	25032	17.32	92.71	5.26	6000	17.31	40.00	5.52
– fibers with interrupted medulla	1254	29.12^{A}	4.65	13.06	4317	20.63^{B}	28.78	5.86
– medullated fibers	714	41.80^{A}	2.64	19.31	4683	33.47^{B}	31.22	13.60
Total/mean	27000	18.52^{a}	100	8.02	15000	23.31^{b}	100	11.34

Means in the same line with the different superscripts differ significantly: A, B at $P \leq 0.01$, a, b at $P \leq 0.05$; n – number of fibers; SD – standard deviation.

ter range, spanning from 30 μm to as much as 120 μm. Similar results were obtained in the current study. The findings of Maisnam [2019] are also consistent with the present results. According to the cited author, the diameter of fine down fibers ranges from 19 to 24 μm and their length – from 2.5 to 12.5 cm. In turn, coarse outer fibers have a diameter of 20 to 120 μm. The diameter of outer fibers may vary widely, whereas down fibers are similar to those of merino wool, and their diameter does not exceed 24 μm. However, in comparison with merino wool, camel hair is less flexible, with a low degree of crimp.

In contrast to the present study, Salehi and Gharahdaghi [2010] did not observe differences in mean hair fiber diameter between male and female camels. Iñiguez et al. [2014], who investigated camel hair fibers used in the regions of Kazakhstan and Uzbekistan, also found that sex did not significantly affect the analyzed parameters, including fiber diameter.

The second experimental factor in this study was camel species (Table 2). The hair of Bactrian camels was significantly ($P \leq 0.05$) thinner than that of dromedaries. Non-medullated fibers collected from both species had identical diameters, but the difference in their proportion exceeded 50%. Non-medullated fibers dominated in the coat of Bactrian camels, whereas dromedary camels were characterized by similar proportions of non-medullated fibers, medullated fibers and fibers with interrupted medulla.

An analysis of fibers with interrupted medulla and fibers with continuous medulla indicated that fibers of

the above categories were thicker in Bactrian camels, and their diameters reached 29.12 µm, and 41.80 µm, respectively, compared with 20.63 µm and 33.47 µm, respectively, in dromedaries ($P \leq 0.01$).

According to Khomeiri and Yam [2015], Bactrian camels give more wool of higher quality than dromedary camels. Iñiguez et al. [2014] demonstrated that mean fiber diameter in adult male dromedary and Bactrian camels was 21.1 µm and 18.0 µm, respectively, which is consistent with the present findings.

CONCLUSIONS

The analysis of wool samples of camels kept in Poland, showed that the hair fibers had a mean diameter of 20.23 µm and could be included to the assortment of fine wools. Fibers obtained from females was thinner than that of males and it was also showed that hair fiber diameter in bactrian camels were about 20% finer than that of dromedaries. Fiber medulla diameter were similar regardless of camel sexes or species.

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PODSTAWOWA ANALIZA OKRYWY WŁOSOWEJ WIELBŁĄDÓW W ZALEŻNOŚCI OD ICH PŁCI I GATUNKU

STRESZCZENIE

Celem badań była analiza grubości włókien z okrywy włosowej wielbłądów występujących na terenie Polski i określenie różnic w strukturze włókien z uwzględnieniem płci i gatunku. Badaniami objęto wełnę pochodzącą od 28 dorosłych wielbłądów, które podzielono względem płci (18 samic i 10 samców) oraz względem gatunku (18 dromaderów i 10 baktrianów). Próbki wełny były pobierane w miesiącach maj–lipiec 2020 roku na wysokości ostatniego żebra. Grubość 42000 włókien ustalano zmodyfikowaną metodą mikroprojekcyjną. Poszczególne włókna sklasyfikowano w 3 kategoriach jako: bezrdzeniowe, z rdzeniem przerywanym i rdzeniem ciągłym. Badania wykazały, że średnia grubość włókien wełny wielbłądów utrzymywanych w Polsce wynosiła 20,23 µm. Najcieńsze były włosy bezrdzeniowe i ich grubość wynosiła 17,32 µm. Najmniejsza różnica statystyczna (przy $P \leq 0{,}05$) w grubości włókien w zależności od płci wystąpiła w przypadku włókien bezrdzeniowych. Samce cechowały się większą od samic średnią grubością włókien, szczególnie okrywowych. Nie wykazano różnic w grubości rdzenia włókna w zależności od płci i gatunku wielbłądów. Wełna pozyskana od baktrianów była cieńsza, a udział włosów bezrdzeniowych był ponad 50% wyższy aniżeli u dromaderów.

Słowa kluczowe: wełna, średnica włókien, dromadery, baktriany, włókna bezrdzeniowe, włókna rdzeniowe

Katarzyna Ząbek https://orcid.org/0000-0002-9507-6029
Jan Miciński https://orcid.org/0000-0003-3167-5476