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The Comparison of Physical Characteristics of Anatolian Native Goat Down Fibers With Cashmere

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ABSTRACT

Very fine and soft down fibers of native goats can have a potential as a valuable raw-material source for high-quality products. Therefore, down fibers were collected from native goats raised in different regions of Turkey, then their physical properties were analyzed and results were compared with cashmere fibers. Along with fiber diameter and fiber length, which are the most important parameters regarding spinnability of a textile fiber, fiber scale characteristics of Anatolian native goat down fibers were reported for the first time. In this respect, scale pattern, mean scale density, cuticle scale height, curvature, visual fiber crimp were analyzed as well as fiber tenacity and breaking elongation properties. The economical potential of these fibers in Turkey were also investigated. The findings of this work showed that average fiber fineness changed between 14-19 µm while the single fiber length varied as 33.0–61.0 mm. The mean scale density and cuticle scale height were between 6-7 scales/100 µm and 0.41-0.55 µm, respectively while the visual crimp frequency was 5-6 crimps/cm. On the other hand, the average tenacity and breaking elongation was above 12 cN/tex and 28%, respectively. These results show that these native goat down fibers, that have been wasted mostly, have very similar properties to cashmere fibers with adequate properties for spinnability, hence they have a potential for high-quality textile products as a substitute for cashmere fiber.

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KEYWORDS
Luxury fibers, rare fibers, cashmere, native hair-goat, down fiber

1. INTRODUCTION

Mainly, there are four main types of fibers obtained from goats: Outer coat of coarser guard hairs, fine down hairs (undercoat), mohair fibers and cashgora fibers. The down fibers obtained from cashmere goat, hair goat and other goat species have two types of fibers except for angora goats: Coarse fibers from primary follicules and fine down fibers from secondary follicules. The most valuable of these are down fibers or more specifically cashmere fibers as even very low blend ratio, e.g. 2.5%, within a fabric can alter fabric touch and softness dramatically. Called as “fiber of kings”, cashmere fibers have long been a valuable source regarding their luxurious softness (1). Cashmere fibers are defined as down fibers or undercoat fibers obtained from cashmere goats (*Capra hircus laniger)* indigenous to Asia (2). On the other hand, although cashmere fibers are defined as fibers obtained from cashmere goats mainly from China, Mongolia, Tibet, Afghanistan and Iran, it has also a common use for down fiber finer than 19 µm obtained from goat species except Angora and Cashgora goats (3). Cashmere first becomes known in Europe during the 17th century as cloth woven in the Himalayas and made into shawls and stoles. A French company, founded in 1836 by M Audresset pioneered the spinning of finer yarn and wider European appreciation of cashmere as a fiber rather than as shawl developed towards the end of 19th century (4).

Cashmere undercoat fibers are composed of a cortical layer and epidermis without medulla. These fibers are categorized as first quality when they are finer than 15.5 µm or second quality when their fineness is between 15.5-19.0 µm (5). On

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the other hand, cashmere fiber fineness and quality can vary according to the region of the fiber obtained as finest of fine cashmere grows on the goats living north of the 40th parallel in Inner Mongolia (4). China produces the best quality as Chinese cashmere is finer having an average diameter of between 12.5 to 16.0 µm, with 15 µm being a standard fiber while the length is greater than 32 mm, with a measured length of around 46 mm being considered a long fiber (1). The average fiber fineness is reported as 16.0-18.5 µm for New Zeland and Australian cashmere (6) while it can vary between 16.0 to 19.5 µm for Afghanistan and Iran cashmere (2). Finer cashmere fibers are mainly preferred for knitted products while coarser ones (17 µm and above) are usually used in weaving such as for suiting (7). The color of cashmere is another important parameter for trade quality as white fibers are much preferred mainly obtained from goats in the Gobi Desert region. On the other hand, the outercoat or guard hairs, made up of the epidermis, cortical layer and medulla, are very coarse (average 62 µm) with very irregular in diameter while fiber length is between 38-130 mm (1). Therefore, these outer coat hairs offer limited value for textiles and they are used for mainly tents, sacks or similar rough products in rural areas.

Hair goats have been farmed in Anatolia for many centuries as one of the main sources of meat, milk, leather and fiber. These goats have two types of hair fiber: Coarse outercoat hairs with fineness ranging between 60–90 µm; and fine down-hairs that have fineness between 13-19 µm with down-hair amount in between 40.0-51.4 g per goat, significantly lower value compare to the amount of cashmere undercoat fibers per goat (3). For cashmere goat, it is typically around 100 g per goat per year while Chinese cashmere goat yields more fiber than elsewhere in the world producing up to 500 g per head per year (4). Fine down-hair fibers shed in spring or early summer time and if they are not collected by farmers separately, which is the common case in Turkey, a valuable fiber source that can be used as a substitute for cashmere fibers have been lost without any use. For example, a survey carried out in the South Anatolian region of Turkey points out that only 2% of the farmers are collecting these valuable fibers (8).

The numbers of works investigating down fiber properties of native goats in Turkey are very limited. Furthermore, these works provide few or even no data regarding spinnability or use of these fibers in textiles. In one of the most detailed studies available in this field, fiber properties of down fibers collected from Antalya region were investigated (3). The average fiber diameter was 16.5±0.27 µm and 15.8±0.12 µm for male and female goats, respectively. An overall fiber diameter of 16.2±0.16 µm and coefficient variation of 7.9% was reported while fiber length was given as 2.2±0.10 cm with a coefficient variation of 36.4% concluding that these fibers were quite uniform in terms of their fineness while that was not the case for fiber length. This work also indicated that fibers get coarser as the age of goats increases. The same researcher classified available fibers in that region in terms of their color as light brown fibers were 48.4%, gray fibers were 20.3% and white fibers were 17.1% indicating that these figures are in parallel to the market demand as the world cashmere market demands more white and brown colored fibers. In another study, down fiber properties were also studied but in Adana region this time (9). They reported that fibers get coarser as height above sea level increases; e.g. mean fiber diameter at Tufanbeyli was 15.0 µm while it was 14.1 µm at Karaisalı and 13.8 µm at university research farm with a conclusion that these fibers are suitable for textile industry. However, this study showed that there was no statistical correlation between fiber fineness and goat age. On the other hand, average down fiber amount per goat was 16.38 g, 21.63 g and 4.5 g at Karaisalı, Tufanbeyli and at university research farm, respectively. More recently, properties of outercoat-hairs and down fibers were investigated by Kuloğlu in Yozgat region (10). Average down fiber fineness was reported as 18.43±0.45 µm for males while it was 18.20±0.51 µm for females. In this work, tenacity properties were also investigated but only coarse outercoat fibers were tested, therefore providing no information on down fiber strength. In a similar work, Karakuş et al. investigated the phenotypic correlation between physical properties of outercoat fibers and down fibers indicating that as fiber gets coarser, fiber bundle length was increasing, similar to the wool (11).

Different from the above studies, main fiber characteristics of native hair goat down fibers collected from different parts of the country were analyzed in detail to investigate their potential for textiles for high value-added products. In this respect, 16 different samples, collected from 10 different farms in south and west Anatolian regions of Turkey, were evaluated. In the first part of this work, mean fiber diameter and fiber length ,as well as scale patterns, were analyzed. In the second part of the work, fiber characteristics were evaluated further by analyzing cuticle scale height, scale density, visual crimp frequency, fiber tenacity and breaking elongation values. Then, the obtained results were compared with available data in the literature regarding cashmere fibers and hair goat down fibers. This work reports for the first time fiber scale characteristics, such as scale pattern, scale density and scale height, as well as fiber curvature and crimp values of Anatolian native goat down-hairs and compares with cashmere fiber.

2. ECONOMICAL POTENTIAL OF GOAT DOWN FIBERS IN TURKEY

The hair-goat population in Turkey is over ten million with an increasing trend since 2009 as shown in Figure 1 corresponding to over 98% of the overall goat population in the country. Available statistics also suggest that 50% of the hair-goat population has been in Mediterranean and South Anatolian regions (12). As the available data is analyzed further, it is clear that sheared goat population is 91% of overall hair-goats indicating a potential of goat fiber amounts in Turkey. On the other hand, there is no individual data regarding the amount of coarse outercoat fibers and fine down fibers each as down fibers were usually not collected. However, the figures above indicate that there is a potential amount of fine down fibers in Turkey although these cashmere-like valuable fibers are not collected and used for value-added products in the textile industry. This might be mainly because of low awareness of their value among the farmers, high labor cost involved, low fiber output per goat and lack of processability of these fibers especially in terms of dehairing. However, the importance of goat down fibers was already pointed out by Dellal et al. (8) emphasizing the need for increased awareness among farmers. On the other hand, same researchers reported that average down fiber output was 40.0-51.4 g per goat compares to 100 g and above for cashmere goat. Down fiber and coarse outercoat hair obtained per goat was also reported as 46 g and 410 g, respectively (13). This figure regarding down fiber output per goat may seem to be a small amount at first sight, however, one needs to consider that even small blend ratio of these fibers might affect fabric touch and feeling substantially. Therefore it can lead to much higher value-added products once their significance was understood and suitable mechanisms were built to collect these by farmers every year. The recent figures show that Turkey has begun to export 35.6 tonnes down fiber in 2016 indicating that there is a new demand in abroad for these fibers, however with an average price of 1.80 USD/kg which is, in fact, well below the real value of these fibers (12). Therefore, further studies are needed to process these rare fibers for higher value-added products in the textile industry.

At this point, it is worth to emphasize the importance of cashmere-like down fibers by briefly indicating cashmere fiber properties in comparison with other rare hair fibers. This is summarized in Table 1 showing that cashmere fibers commands some of the highest prices in the world of luxury fibers, only vicuna but not approaching commercial quantities, achieve higher prices than cashmere (4). Annual production of cashmere in the world can change from year to year depending mainly on market demand as 16.000 tonnes of raw cashmere are produced globally each year while 50% is lost to scouring and dehairing leaving about 8.000 tons (14) or even less than 7.000 tonnes (15), but still without loosing its economic value for very high-quality products for higher segments. China is the main supplier (over 75% of the world's production) and Mongolia, Afghanistan, Iran and other countries follow (16). Regarding consumption of these special fibers, Italy and Scotland have the highest share while the number of spinning and knitting mills has increased in China and Mongolia recently following improved dehairing technology showing continuous interest for these very special fibers. When the import data for cashmere fiber and cashmere products in Turkey for last five years is analyzed, it is over 700.000 USD for cashmere fiber and over 5 million USD for cashmere products showing the demand in the industry (12).

As a result, there are over 300 tonnes of down fiber production capacity annually when one considers the native hair-goat population in Turkey, and this might correspond to 6% of world cashmere fiber production indicating that there is a need for further studies to increase awareness regarding these almost wasted but quite valuable fiber sources. In this respect, good cases, such as the cashmere programme initiated in South Africa earlier (17), can be an example to improve the potential of indigenous goats breeds in Anatolia.

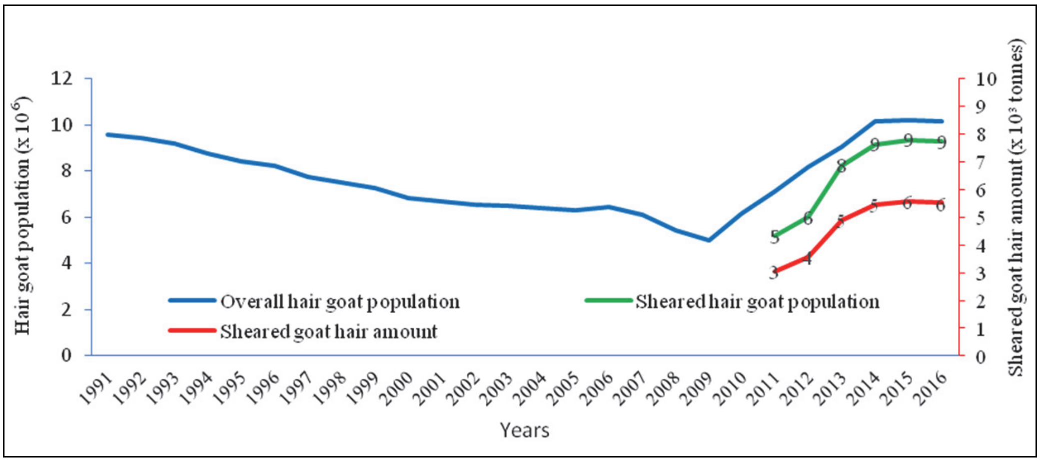


Figure 1. Hair-goat population in Turkey over the years (12)

Table 1. Main properties of various luxury fibers (6)

	Fiber fineness (µm)	Fiber length (mm)	Fiber output (kg/head/year)	Annual production (tonnes)	Price (US$/kg)
Alpaca fiber	20-36	200-550	3-5	4000-5000	2-10
Angora fiber	14	60	0.42-0.82	3000	20
Cashgora fiber	18-23	30-90	50% of fleece	50	45
Camel hair	18-24	36-40	3.5-5	4500	9.5-24
Cashmere fiber	**12.5-19**	**35-50**	**0.1-0.16**	**9-10000**	**100-130**
Mohair fiber	23-40	84-130	4-10	7000	8
Vicuna fiber	12-25	30-40	0.2	5	360
Yak fiber	15-20	35-50	0.1	1000	20

3. MATERIAL AND METHOD

In this work, down fibers were collected from 10 different farms, mainly in the south and west Anatolia such as Konya, Isparta, Balıkesir, Bursa and Gaziantep regions. These fibers were classified into sub-categories in terms of their color so that the change in fiber properties regarding fiber color could also be analyzed resulting 16 different fiber samples in total as summarized in Table 2.

During the shedding session of down fibers in 2014 springtime, the down fibers were collected from goats manually by using special combs as shown in Figure 2a. Naturally, there were still coarse outercoat hair fibers upheld among these down fibers (Figure 2b), so dehairing process was needed as it is the usual case with cashmere fibers as well. The dehairing process was carried out by removing coarse outercoat-hair fibers manually (Figures 2c and 2d).

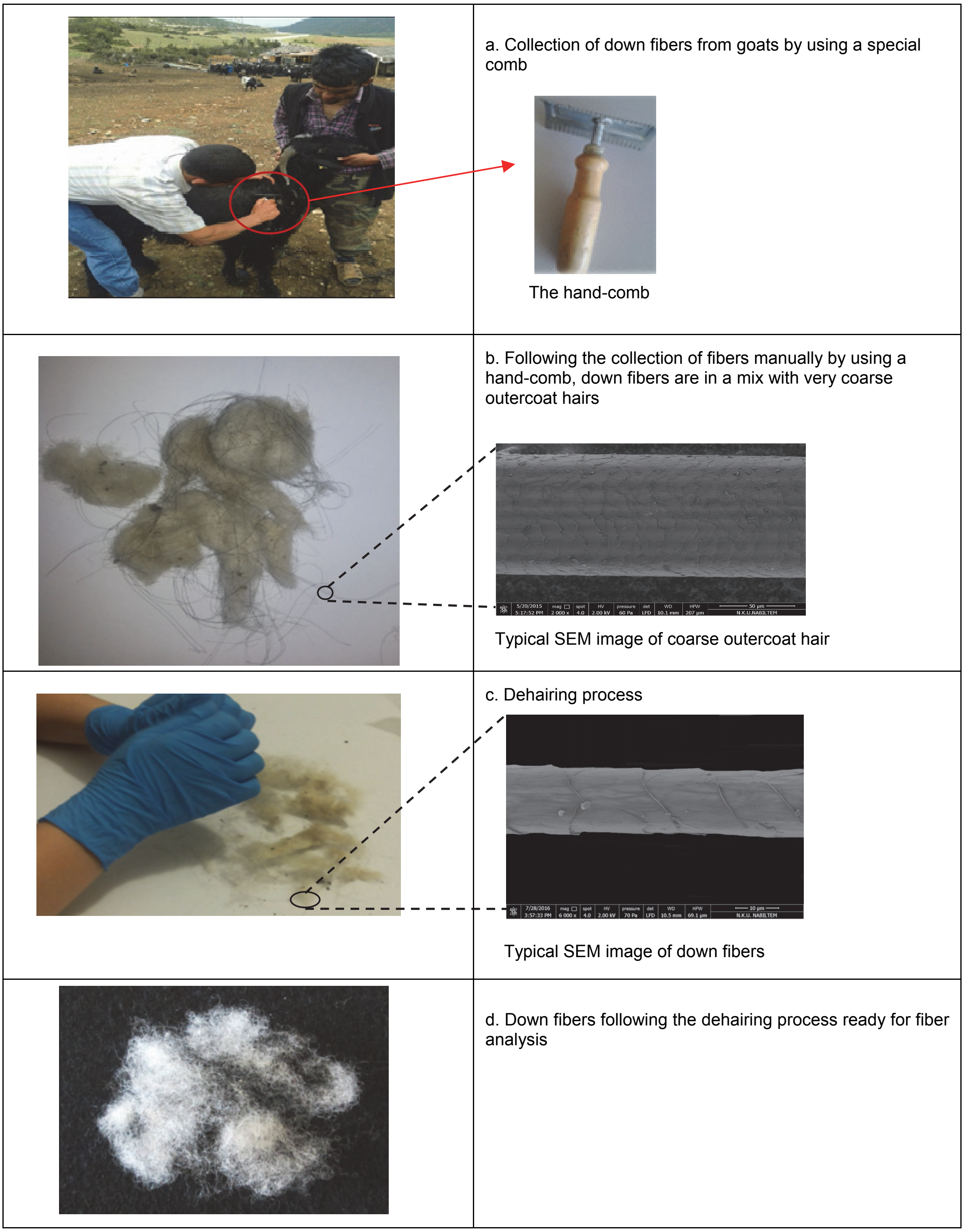


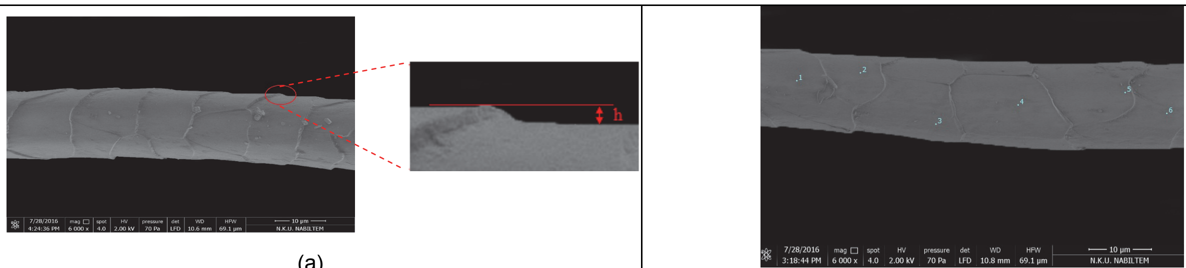
Figure 2. The collection of down fibers

Table 2. Down fiber samples collected from 10 different farms

Farm Number	Sample code	Fiber color	Hair goat age	Gender	Location
1	A1	Brown	5	Female	Beyşehir/Konya
2	B1	Cream	4	Female	Derebucak/Konya
	B2	Brown	3	Female	Derebucak/Konya
3	C1	Brown	4	Male	Derebucak/Konya
	C2	Cream	4	Female	
	C3	Gray	4-5	Female	
4	D1	Brown	4	Female	Gelendost/Isparta
5	E1	Cream	4	Female	Derebucak/Konya
6	F1	Cream	4	Female	Beyşehir/Konya
	F2	Brown	3	Female	Beyşehir/Konya
7	G1	Brown	-	Female	Derebucak/Konya
8	J1	Cream	-	-	Balıkesir-Bursa
	J2	Brown	-	-	Balıkesir-Bursa
9	K1	Cream	-	-	Karatay/Konya
	K2	Brown	-	-	Karatay/Konya
10	R1	Cream	-	-	Gaziantep

In the first part of this work, mean fiber diameter, fiber curvature, fiber length as well as fiber scale patterns were analyzed. In the second part of the work, fiber characteristics were evaluated further for fiber scale height, mean scale frequency, mean visual fiber crimp, fiber tenacity and breaking elongation analysis by choosing four samples (i.e. A1, B1, C2, and E1) so that overall characteristics of these specialty fibers can be compared with cashmere fibers in a detailed way.

The mean fiber diameter (MFD) and fiber diameter distribution including coefficient of variation and fiber curvature (degree/mm) were measured by OFDA 2000 tester according to IWTO-47-2013 using 5 separate over 2000 snippet measurements each (18). Single fiber length was analyzed according to TS 1140 by taking 50 fibers randomly for each sample (19). Single fiber tenacity and breaking elongation test was carried out according to ASTM D-3822 by using Prowhite single fiber tensile tester and 10 fibers were tested for each sample type (20). Following the tensile tests, fiber tenacity values were calculated by using simple conversion between mean fiber diameter and linear density as suggested by Hunter and Kruger earlier (21). Visual fiber crimp was determined under lighted magnifier by counting crimp numbers per unit length as randomly chosen 50 fibers were analyzed for each fiber sample. The fiber scale pattern and surface characteristics were investigated by using FEI, QUANTA FEG 250 model scanning electron microscope at N.K.U. Central Research Lab by analyzing 10 different single fiber images for each sample type. Before each analysis mentioned above, fiber samples were conditioned in standard atmosferic conditions for 24 hours minimum. Following SEM images, cuticle scale height (CSH) and mean scale density (MSD) analysis were carried out by using Adobe Photoshop CS6 as described in Figure 3a and b and following suggestions by Varley (14). Prior to these detailed analyses, the fiber samples were washed in mild conditions carefully in a series of beakers to eliminate any foreign particles from the fiber surface. The washing process was carried out by using 3 g/l sodium carbonate and 3 g/l washing agent at 50 °C for 20 min following rinsing at 60 °C and then cold rinsing for 10 min.



(a) (b)

Figure 3. Analysis of cuticle scale height (a) and mean scale density (b)

4. RESULTS AND DISCUSSIONS

4.1. Analysis of Average Fiber Fineness, Single Fiber Length and Fiber Curvature

Average fiber fineness and fiber staple length are main parameters for spinnability of fibers as well as their variations as the minimum number of fibers that can be in yarn cross-section (n) are defined as a function of these main wool fiber parameters (22). It was reported by Lawrence that average cashmere fiber diameter of a sample of the undercoat was within 12.5 to 21 μm with CV% in the order of 18% to 20%, that means they are fairly uniform in fineness (1). However, CV% of fiber diameter for cashmere was also given as 20-25% by Phan earlier (2).

Following OFDA tests, the mean fiber diameter (MFD) values were summarised in Figure 4 together with the coefficient of variations in diameter. Commercial cashmere and mohair fiber available in worsted yarn industry were also tested and their results were included for a better visualization in comparison to down fibers. The results showed that MFD was below 16 μm for seven fiber samples while it was between 16-18 μm for six fiber samples, and only two fiber samples (J1 and J2) seemed to have MFD higher than 19 μm. This indicates that goat down fibers analyzed in this work are similar to cashmere fibers in terms of their fineness as depicted in Figure 5. Also, these findings are in parallel to the results of other research works regarding goat down fiber fineness in Turkey, such as Bolat (9), Karakuş (11), Kuloğlu (10) and Dellal (3). On the other hand, fiber diameter CV% for all tested samples was between 19.6-25.3%, except only fibers J1 and J2 while J2 was the coarsest one (20.3 μm) with the highest CV% in diameter (29.5%) probably due to genotypes resulted from several level of crossbreeding. Consequently, the overall findings show that in general goat down fibers analyzed in this work have also similar characteristic to cashmere in terms of their fiber diameter CV% as it was reported between 20-25% earlier (2). At this point, it is also worth to mention that fiber diameter CV% was 29% when a typical commercial cashmere fiber (MFD: 18.71 μm) was tested. This indicates that these values are already within the acceptable limits for commercial use.

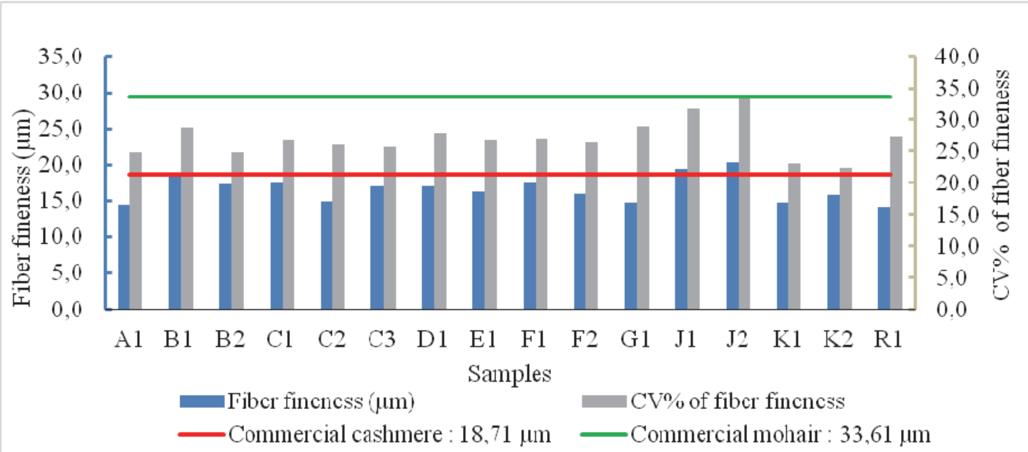


Figure 4. The results of MFD analysis

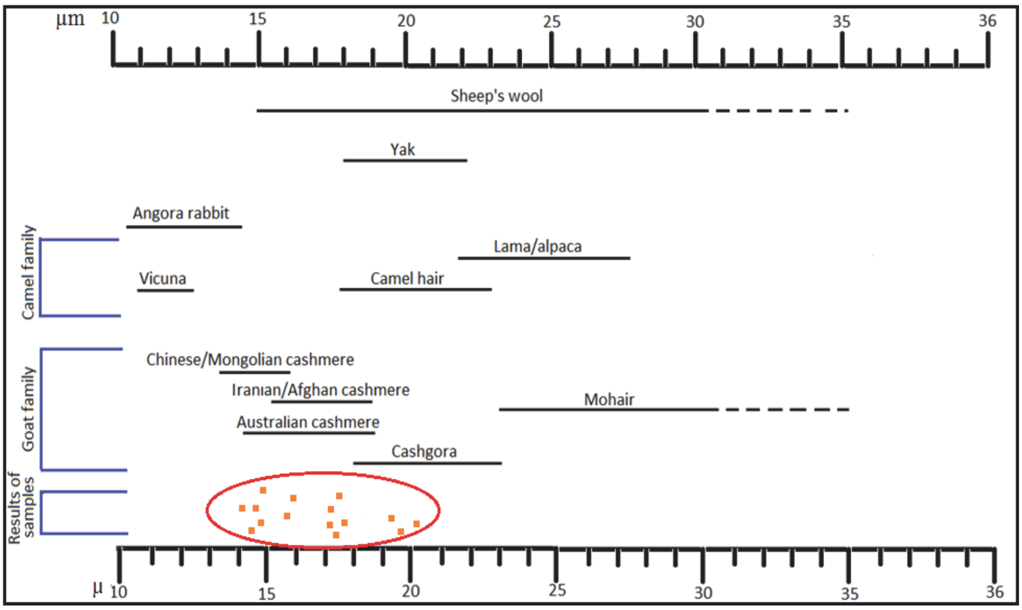


Figure 5. Distribution of MFD values of this work scattered (in red color) on the scale provided for other luxury fibers earlier by Phan (2)

In this part of the work, also fiber curvature values were tested and the results were given in Figure 6 together in comparison with the general classification of fiber curvature at three levels, i.e. low, medium and high, described earlier (23). The results showed that curvature of hair-goat down fibers was between 58.4-94.2 degrees/mm, i.e. these fibers have medium level curvature. Interestingly, the curvature of fibers J1 and J2 were lower compared to other fibers collected and analyzed, although they were still in the medium category. In fact, this is quite consistent and expected result considering that these two fibers are also coarser compare to others since fiber crimp or curvature becomes less when the wool fiber gets coarser.

Regarding single fiber length, the test results were given in Figure 7 including its variation as well as the average values obtained for commercial cashmere and mohair fibers tested in this work. The results showed that average fiber length was between 33.0 and 61.0 mm and these fibers have similar characteristics to the cashmere in terms of their length. Also, all available data for fiber length regarding cashmere fibers and down fibers were summarized in Table 3 indicating that these fibers can be processed in staple fiber spinning line without any difficulty.

4.2. Evaluation of Surface Structure and Scale Pattern of Fibers in General

Although cashmere goats are of different strains and live in a very large area, it is known that their down fibers exhibit quite a high similarity in terms of their surface structures or scale patterns. The cuticle scales are predominantly cylindrical or semi-cylindrical in cashmere fibers; i.e. each scale envelops the entire or half of the fiber shaft (5) and a typical example was shown in Figure 8 in comparison with Merino wool. The typical surface images of fibers analyzed in this work were given in Figure 9. When these images were analyzed, it was obvious that they exhibited similar scale pattern to cashmere fibers in general, with an exception of fiber J2 only which was the coarsest fiber in this work with the lowest curvature.

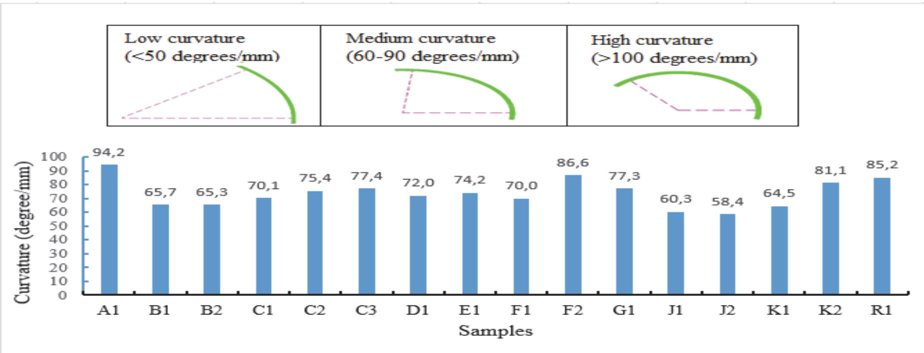


Figure 6. The results of fiber curvature analysis

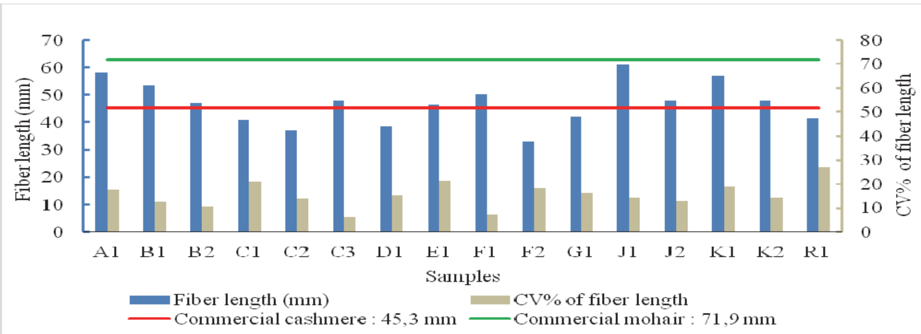


Figure 7. The results of average single fiber length analysis

Table 3. The available data in the literature regarding down fiber and cashmere fiber length

Region or country	Species	Staple length (mm)	Reference
China	Cashmere (2nd quality)	24.0	(2)
Turkey	Norduz goat Hair-goat	24.4* 27.5*	(11)
China	Cashmere (Super quality)	36.0	(2)
Turkey (Yozgat/Yerköy)	Hair-goat (Capricorn)	38.0 (male) 51.0 (female)	(10)
-	Cashmere	35.0-50.0	(6)
-	Cashmere	25.0-90.0	(24)
-	Cashmere	32.0-90.0	(1)
China**	Cashmere	45.3	-

* Hauter length
**Commercial cashmere

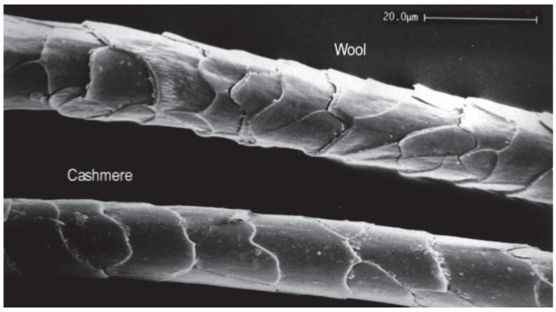


Figure 8. Typical images of Merino wool and Chinese cashmere (25)

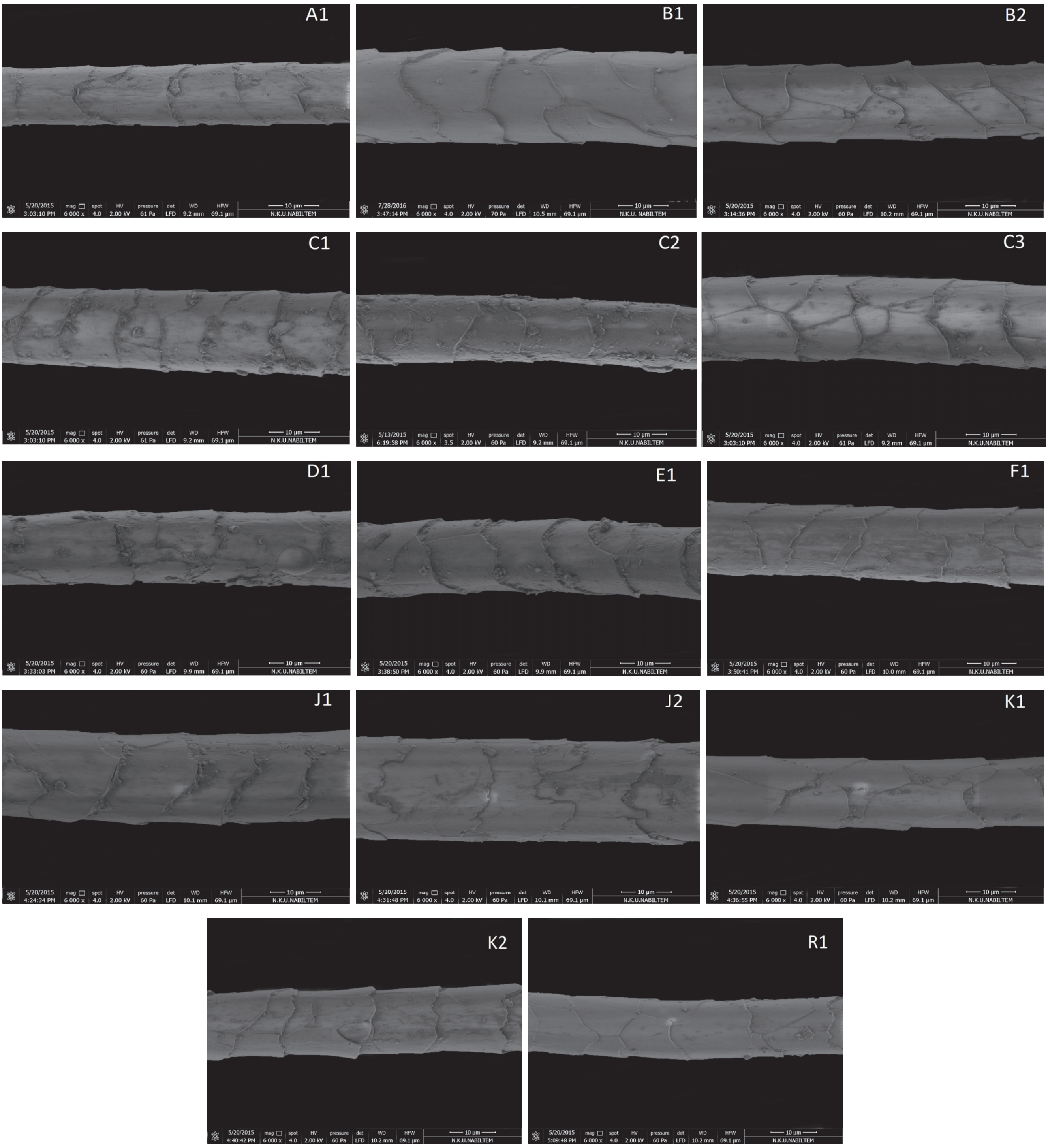


Figure 9. Typical examples for SEM images of down fibers analyzed in this work

4.3. Analysis of Cuticle Scale Height and Mean Scale Density

Cuticle scale height (CSH) is the most important parameter for distinguishing sheeps' wool and other specialty fibers as it is higher than 0.8 µm for sheeps' wool but below 0.8 µm for other specialty fibers (2). The scales are less pronounced and more widely spaced in specialty hair fibers in general, therefore they have smoother surfaces compare to wool fiber (26). Regarding cashmere fiber, it is composed of a cortical layer and epidermis and their scales slightly project beyond the cortical layer to give fiber a serrated appearance (1). Average CSH for cashmere fiber was given as 0.4 µm (6). On the other hand, the findings of this work showed that CSH was between 0.41-0.55 µm. These results were listed in Table 4 together with available data in the literature including cashmere and wool fibers indicating that goat down fibers investigated in this work has similar characteristics to cashmere fibers in terms of their CSH characteristics as well.

Table 4. The results of CSH analysis in comparison with available data in the literature

Fiber type	CSH (µm)	Sample code or Reference
Cashmere	≈ 0.40	(6)
Goat fiber	0.41	A1
Goat fiber	0.50	E1
Goat fiber	0.51	C2
Goat fiber	0.55	B1
Cashmere	0.56	(14)
Cashmere	< 0.80	(2)
Wool	>0.80	(2)

On the other hand, mean scale density (MSD) is defined as the number of scales per 100 µm fiber length and it is another important parameter for identification of sheeps' wool and other specialty fibers. This parameter can affect brightness and smoothness of fiber, therefore contributes well to the appearance of a final product. The findings showed that average MSD values changed between 6-8 scales/100 µm for goat down fibers investigated. The MSD can range from 5-7 scales/100 µm for classical Asian cashmere to 8 scales/100 µm for Australian cashmere while it is 9-10 scales/100 µm for wool as shown in Table 5. This result also indicates the similarity of down fibers analyzed in this work to the cashmere fibers except for Australian cashmere in terms of their MSD characteristics.

4.4. Analysis of Visual Crimp Frequency

Fiber visual crimp frequency (VCF) has been shown to influence the mechanical, wear and handle attributes of fabrics, therefore can provide important data for the final product (27). However, there is no specific data available in the literature about crimp level of cashmere fibers although it is known that cashmere fiber has lower crimp compare to wool fiber which is around 12 crimps/cm (24). Having lower crimp level is attributed to more mesocortical cells within the cashmere fiber compare to wool (28). Regarding down fibers of native goats, Kuloğlu (10) reported earlier 2-3 crimps/cm. According to the results in Table 6, VCF was between 5-6 crimps/cm for down fibers analyzed, i.e. they have much less VCF compare to wool fiber but exhibit similar visual crimp level to cashmere fibers as expected. The results in Table 6 also showed that there was an agreement between VCF determined in this part and curvature levels provided by OFDA test.

Table 5. The results of MSD analysis in comparison with available data in the literature for cashmere and wool

Region or country	Fiber type	MSD (number/100 µm)	Sample code or Reference
-	Cashmere	5-7	(24)
-	Cashmere	6-7	(1)
Turkey (Konya/Derebucak)	Goat down fiber	6	C2
Asia	Cashmere	6-7	(2)
Turkey (Konya/Beyşehir)	Goat down fiber	7	A1
Iran	Cashmere	6-8	(6)
Turkey (Konya/Beyşehir)	Goat down fiber	8	B1
Turkey (Konya/Beyşehir)	Goat down fiber	8	E2
Australia	Cashmere	>8	(2)
-	Wool	9-10	(2)

Table 6. The results of VCF and fiber curvature analysis

Sample	VCF (crimps/cm)	Curvature (degree/mm)
A1	6	94.2
B1	5	65.7
C2	5	74.4
E1	5	74.2

4.5. Analysis of Fiber Tenacity and Breaking Elongation

According to available data in the literature regarding single fiber tenacity of cashmere; it is 7.0-15.5 cN/tex for Australian cashmere (MFD 15.1-17.9 µm), 8.2-11.2 cN/tex for Chinese cashmere (MFD 13.6-13.9 µm), 16.2 cN/tex for Iranian cashmere (MFD 17,4 µm) while it is reported as 10.19 cN/tex by another study (MFD 15.0-16,5 µm) (29, 30). Also, average tenacity for wool is given as 11.0-14.0 cN/tex while breaking elongation changes between 29.8%-42.9% (31). The tenacity and breaking elongation results of goat down fibers given in Figure 10 indicate that these fibers have similar or even higher tenacity level than cashmere fibers. For example, the tenacity of fibers B1 and C2 was above 21 cN/tex, while A1 and E1 had similar tenacity with cashmere. Results for A1 and E1 were also in parallel to the previous findings reported by Dellal as average tenacity and breaking elongation values were 12.95 cN/tex and 32.5%, respectively for down fibers of native goats (32). The breaking elongation values of fibers investigated in this work were between 28-41%, in fact being very similar to the behavior of wool fibers as might be expected. Therefore, no difficulty would be expected in terms of the strength characteristics of these fibers in yarn spinning.

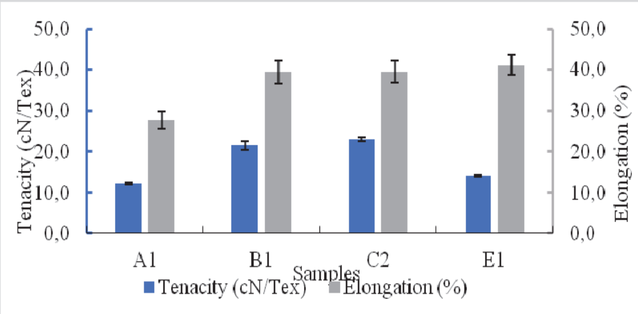


Figure 10. Fiber tenacity and breaking elongation results

5. CONCLUSIONS

Superior characteristics of cashmere fibers, called as “fibers of kings”, make them valuable source for high-quality textile products. In this regard, the importance of a valuable cashmere-like down fiber of native hair-goat was highlighted in this work considering the potential of their use for high value-added products in textiles. For this aim, down fibers were collected from 10 different farms along the country from south to west Anatolia and then classified into sub-categories in terms of their colors. Following dehairing process, the fibers were analyzed for their mean fiber diameter, fiber curvature, single fiber length as these were the most critical parameters for defining spinnability of wool type fibers. Scale characteristics of these fibers were also analyzed and reported for the first time in literature. As a result, fiber scale pattern, mean scale density, cuticle scale height, curvature, visual crimp frequency as well as fiber tenacity values were investigated in detail and each result was compared with available properties of cashmere fiber.

The findings of this work indicated that mean diameter of the fibers collected from various parts of the country was between 14-19 µm while average single fiber length was between 33.0-61.0 mm showing that these fibers have similar characteristics of cashmere fibers in terms of these two main fiber properties. The variation in fiber diameter was also low (21.7-25.3%), within acceptable limits for wool and cashmere fibers. The results regarding fiber scale patterns also indicated that these fibers had the similar structure to cashmere fibers as cuticle scales were predominantly cylindrical or semi-cylindrical and each scale was enveloping entire or half of the fiber shaft just like cashmere fibers. The results showed that mean scale density and cuticle scale height of these down fibers were between 6-7 scales/100 µm and 0.41-0.55 µm, respectively while the visual crimp frequency was 5-6 crimps/cm, i.e. within the values of cashmere fibers. The curvature of these fibers was between 58-94 degree/mm, i.e. at the medium level. On the other hand, average fiber tenacity and breaking elongation was above 12 cN/tex and 28%, respectively, again confirming that tenacity characteristics of these fibers were similar to cashmere and within spinning limits like wool fibers. However, it is worth to note that there was one sample (fiber sample collected from Balıkesir-Bursa region, with the average diameter of 20.3 µm and diameter variation of 29.5%) having an average diameter slightly over the limit of cashmere fibers and high variation in diameter. This fiber sample had also different scale pattern and very low crimp compare to others analyzed in this work possibly due to genotypes resulted from several level of crossbreeding.

Consequently, overall findings show that down fibers of native goats have similar characteristics to cashmere in general and can be used in textiles as a substitute for cashmere fibers which are the most expensive hair fibers after vicuna. However, the real value of these fiber sources has not been known well in Turkey, therefore almost wasted without any significant use. On the other hand, awareness about the value of these fibers, labor involved during fiber collection, classification of fibers following collection, low fiber yield per goat, know-how needed in downstream processing including the most critical dehairing process seems to be the main obstacles. Under these circumstances, it can also be argued that goat genetic improvement programs are needed and should include such characteristics of fiber yield and homogenous fiber quality as selection criteria. Therefore, further studies are necessary in this field to improve prospects of these almost wasted but in fact quite valuable fibers.

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6. REFERENCES

1. Lawrence, C. A., 2003, Fundamentals of Spun Yarn Technology, CRC Press, Washington, United States of America, pp: 46-47.
2. Phan K. H., 1991, Electron Microscopy and The Characterization of Keratin Fibres, Commett Eurotex, Portugal, pp: 47-70.
3. Dellal G., 2001, “Antalya İlinde Yetiştirilen Kıl Keçilerinden Elde Edilen Alt Liflerin Tekstil Sanayii Açısından Uygunluklarının Belirlenmesi”, Tarım Bilimleri Dergisi, Vol:7 (2), 131-134.
4. Watkins, P. and Buxton, A., 1992, Luxury Fibers: Rare Materials for High Added Value, The Economist Intelligence Unit Special Reports, No.2633, United Kingdom, pp: 6-44.
5. Phan K. H. and Wortmann F. J., 1996, “Identification and Classification of Cashmere”, Europe Fine Fibre Network, Vol:4, pp: 45.
6. Dalton J., 2001, Cashmere, in Silk, Mohair, Cashmere and Other Luxury Fibres (Ed.: Franck R.R), Woodhead Publishing, Cambridge, United Kingdom, pp: 133-170.

7. Russel A., 1998, The Establishment of Cashmere Production in The European Union, (A Feasibility Study Undertaken for the European Network for Livestok Systems in Integrated Rural Develepment), Macaulay Land Use Research Institute, Craigiebuckler, United Kingdom, pp: 2-3.
8. Dellal İ., Keskin G., Dellal G., 2002, "GAP Bölgesinde Küçükbaş Hayvan Yetiştiren İşletmelerin Ekonomik Analizi ve Hayvansal Ürünlerin Pazara Arzı", TÜBİTAK Türkiye Tarımsal Araştırma Proje Raporu 2002-2, Ankara, Turkey, pp: 68-69.
9. Bolat Ü., 2006, Cashmere Production Potential and Physical Characteristics of Hair Goats Raised in Adana Region and Its Application Areas in Textile Sector, MSc. Thesis, University of Çukurova, Institute of Natural and Applied Sciences, Department of Animal Science, Adana, Turkey.
10. Kuloğlu B. H., 2010, Some Physical Properties of Coarse and Down Fibers Obtained From Hair Goat Kids, MSc Thesis, University of Ankara, Graduate School of Natural and Applied Sciences, Department of Home Economics, Ankara, Turkey.
11. Karakuş F., Bingöl M., Kor A., Tuncer S., Yılmaz A., Cengiz F., 2010, "Norduz ve Kıl Keçilerinden Elde Edile Üst ve Alt Kıllarda Bazı Fiziksel Özellikleri Arasındaki Fenotipik Korelasyonlar", Ulusal Keçicilik Kongresi Bildiriler Kitabı, Çanakkale Onsekiz Mart Üniversitesi Matbaası, Çanakkale, Turkey, pp: 438-442.
12. Türkiye İstatistik Kurumu, 2016, Hayvancılık İstatistikleri, https://biruni.tuik.gov.tr/hayvancilikapp/hayvancilik.zul, (Date of access: 15.06.2017).
13. Erduran, H., 2010, Kıl Keçisi, in Native Animal Genetic Resources of Türkiye (Ed.: Soysal M. İ.), Tekirdağ, Turkey, pp: 167.
14. Varley R. A., 2006, "A Modified Method of Cuticle Scale Height Determination for Animal Fibers", AATTC Review, pp: 38-41.
15. McGregor B. A., 2012, Properties, Processing and Performance of Rare and Natural Animal Fibres, Rural Industries Research and Development Corporation Publication, Barton, Australia, pp: 6-8.
16. Weijer F., 2011, Cashmere Value Chain Analysis Afghanistan, http://www.ahdp.net/reports/Cashmere%20Value%20Chain%20Analysis.pdf, (Date of Access: 03.01 2015).
17. Braun A. L., 2000, "Adding Further Value to South African Indigenous Goats Through The Production of Cashmere" https://researchspace.csir.co.za/dspace/bitstream/ handle/10204/1198/Braun_2000.pdf?sequence=1&isAllowed=y, (Date of Access: 17.04.2014)
18. IWTO-47-2013, Measurement of The Mean and Distribution of Fibre Diameter of Wool Using an Optical Fibre Diameter Analyser.
19. TS-1140-2005, Yün ve Benzeri Liflerde Lif Uzunluklarının Tayini-Tek Lif Uzunluk Ölçme Metodu.
20. ASTM-D-3822-2014, Standard Test Method for Tensile Properties of Single Textile Fibers.
21. Hunter, I. M., Kruger, P. J., 1967, "A Comparison of The Tensile Properties of Kemp, Mohair and Wool Fibers", Textile Research Journal, Vol: 37 (3), 220-224.
22. Davaslıgil Ş., 1966, Yün İplik Teknoloji ve Makinaları, Teknik Üniversite Matbaası, İstanbul, Turkey, pp: 388.
23. AWTA Ltd. Information Sheets, 2013, "What's All The Fuss About Fibre Curvature?", https://www.awtawooltesting.com.au/index.php/en/resources/fact-sheets/fact-sheet-fibre-curvature/viewdocument, (Date of Access: 06.05.2018).
24. Cook G. J., 2001, Handbook of Textile Fibres, Vol.1: Natural Fibres, Woodhead Publishing, Cambridge, United Kingdom, pp: 79-141.
25. IWTO–58-2000: Scanning Electron Microscopic Analysis of Speciality Fibres and Sheep's Wool and Their Blends.
26. Shamey R. and Sawatwarakul W., 2014, "Innovative Critical Solutions in The Dyeing of Protein Textile Materials", Textile Progress, Vol: 46 (4), 323-450.
27. Tester, D., McGregor, B. A. and Staynes, L., 2015, "Ultrafine Wools: Comfort and Handle Properties for Next-to-Skin Knitwear and Manufacturing Performance", Textile Research Journal, Vol: 85 (11), 1181–1189.
28. Tester, D. H., 1987, "Fine Structure of Cashmere and Superfine Merino Wool", Textile Research Journal, Vol: 57 (4), 213-219.
29. McGregor B. A., 2018, Physical, Chemical, and Tensile Properties of Cashmere, Mohair, Alpaca, and Other Rare Animal Fibers, in Handbook of Properties of Textile and Technical Fibres, (Ed.: Bunsell A.R.), Woodhead Publishing, Cambridge, United Kingdom, Second Edition, pp: 105-136.
30. Rocco F. and Maurizio G., 2010, "Yarn Strength Prediction: A Practical Model Based On Artificial Neural Network", Advances in Mechanical Engineering, 2010, 5.
31. Morton W. E., and Hearl J. W. S., 2008, Physical Properties of Textile Fibers, Woodhead Publishing, Cambridge, United Kingdom, pp: 290.
32. Dellal G., Erdoğan Z., Koyuncu M., Söylemezoğlu F., Pehlivan E., Tuncer S., 2010, Ulusal Keçicilik Kongresi Bildiriler Kitabı (Ed.: Ataşoğlu C.), Çanakkale Onsekiz Mart Üniversitesi Matbaası, Çanakkale, Turkey, pp: 434.