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DETERMINATION OF THE RELATIONSHIP BETWEEN COLOURS AND FIBRE PROPERTIES OF MOHAIR OBTAINED FROM ANKARA GOATS RAISED IN THE SİİRT PROVINCE OF TÜRKİYE

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***ABSTRACT*:** Although mohair fibres are usually white or off-white, mohair from some animals can be coloured (e.g. brown, black or reddish). Reddish brown mohair fibres containing colour pigments are produced in Türkiye and are known as "Gingerline" in the world. In this study, it is aimed to evaluate the physical and mechanical properties of mohair obtained from Ankara goats raised in Siirt province of Türkiye in textile clothing field. For this purpose, three different colours of mohair were obtained and the fineness, length, diameter variation, strength and elongation at break values of these fibres were analysed. It was found that pigmentation had a significant effect on fibre fineness, diameter variation, fibre length and fibre strength. Among the coloured mohair, it can be said that brown mohair is the best quality in terms of both fineness and diameter variation.

Keywords: Angora goat, mohair, pigment

TÜRKİYE'NİN SİİRT İLİNDE YETİŞTİRİLEN ANKARA KEÇİLERİNDEN ELDE EDİLEN TİFTİĞİN RENKLERİ İLE LİF ÖZELLİKLERİ ARASINDAKİ İLİŞKİNİN BELİRLENMESİ

***ÖZ*:** Tiftik lifleri genellikle beyaz veya kirli beyaz olsa da, bazı hayvanlardan elde edilen tiftik renkli (örneğin kahverengi, siyah veya kırmızımsı) olabilmektedir. Renk pigmentleri içeren kırmızımsı kahverengi tiftik lifleri Türkiye'de üretilir ve dünyada "Gingerline" olarak bilinir. Bu çalışmada, Türkiye'nin Siirt ilinde yetiştirilen Ankara keçilerinden elde edilen tiftiğin fiziksel ve mekanik özelliklerinin değerlendirilmesi amaçlanmıştır. Bu amaçla, üç farklı renkte tiftik temin edilmiş ve bu liflerin incelik, uzunluk, çap varyasyonu, mukavemet ve kopma uzaması değerleri analiz edilmiştir. Pigmentasyonun lif inceliği, çap varyasyonu, lif uzunluğu ve lif mukavemeti üzerinde önemli bir etkiye sahip olduğu bulunmuştur. Renkli tiftikler arasında, hem incelik hem de çap varyasyonu açısından en kaliteli olanın kahverengi tiftik olduğu söylenebilir.

Anahtar Kelimeler: Ankara keçisi, tiftik, pigment

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1. INTRODUCTION

Mohair, cashmere, camel wool, alpaca, llama, vicuña, guanaco, angora, yak, musk wool, silk, tasar, muga, eri, etc. fibres are very expensive due to the small amount of production and their properties make these fibres very attractive. These fibres give a distinct status in that society that no artificial fibre gives and are defined as "Luxury Fibre" [1]. The Angora goat is a domesticated small ruminant of the Capra genus of the Bovidae family. As the name suggests, these goats are found mainly in Ankara and its immediate surroundings, the central part of the Central Anatolia Region, and a few local areas in Southeastern Anatolia and the Black Sea Region [2]. The purest specimens with the characteristics of Ankara goat are found in the Ankara region [3]. Besides Ankara, Angora goats are found in Konya, Eskişehir, Çankırı, Afyon, Kastamonu, Kırıkkale, Yozgat, Çorum, Niğde, Bolu, Kırşehir, Karaman, Kütahya and Aksaray provinces in Central Anatolia and Siirt, Mardin, Şırnak and Batman provinces in Southern Anatolia [4]. In Türkiye, approximately 75% of Ankara goats are found in Ankara province [5]. In the 1905 census, it was reported that there were approximately 1 million five hundred thousand mohair goats in Ankara province [6]. Until the early 19th century, Türkiye was the only mohair producer in the world, but towards the end of the 19th century, mohair production became widespread in South Africa and certain regions of the United States of America, especially in Texas and California [7]. Today, the most important mohair producing countries are South Africa and the United States. In addition, Turkey, Argentina, Lesotho, Australia and New Zealand can be listed among other significant mohair producing countries [8]. Approximately 4,570 tonnes of greasy mohair fibre were produced globally in 2023 [9].

The main properties to be measured to characterise the greasy mohair fibres are:

- Fineness (diameter) and its variation
- Length and its variation
- Strength and its variation
- Elongation (elasticity)
- Clean fibre yield
- Medullation / kemp
- Vegetable and inorganic matter (such as dirt and stain) content
- Lustre
- Ondulation (waviness) and
- Colour

The most important parameter affecting the processing, price and end-use of mohair is fibre fineness [10]. In general, Kid mohair is finer than about 30 µm (ranging from about 20 to 30 µm), Young Goat mohair is generally less than 34 µm (ranging from about 27 to 34 µm), and adult mohair is mostly coarser than about 34 µm (ranging between about 30 to 40 µm) [11]. On the other hand, fibre length can differ from animal to animal, as well as varying according to the position on the body of the goat. The fibres are longest at shoulder and shorten from the front of the body to the back [12]. Mohair fibres can be classified according to the actual fibre length as follows:

- Short fibres: those between 11-15 cm
- Medium fibres: those between 15-23 cm
- Long fibres: those longer than 23 cm [13].

Although mohair fibres are usually white or off-white, mohair from some animals can be coloured (e.g. brown, black or reddish). The colour of these fibres comes from melanin pigments in the cortical cells forming the cortical layer [13]. Coloured Angora goats are difficult to breed because breeders need to consider fibre colour, fibre character and conformation simultaneously. Colour genetics is complex. Pigments in goats consist of two main types, eumelanin and pheomelanin, which can be found in varying combinations. Eumelanin is responsible for the colours black, bluish grey and chocolate brown, and in most goats, eumelanin occurs in only one colour unless bleached by the sun or altered by another environmental factor. Feomelanin is responsible for tan, cream and red colours. The position of the eumelanic and pheomelanic areas on the goat determines the basic colour of the goat. The white areas in coloured goats are not pigmented. This phenomenon is called "white spotting". The final colour of the goat results from the interaction of eumelanin (black/brown), pheomelanin (red brown/tan/cream/white) and white spotting (white) [14].

In addition to the white mohair goat in Türkiye, there is a significant presence of Angora goats with coloured, pied and black mohair in the provinces of Mardin, Siirt and Şırnak in the South Eastern Anatolia Region [15]. Reddish brown mohair fibres containing colour pigments are produced in Türkiye and are known as "Çengelli" in Türkiye and "Gingerline" in the world [14]. Coloured mohair goats have a small body. The mohair covering the body is black, white, grey, light red, brown, buff and yellow. It is also fine, curly and lustrous. In coloured mohair goats, mohair covers the whole body except the face and legs. In these goats, the head is small and elegant, the eyes are bright and lively. Horniness is a general breed characteristic and is weak in females [16]. The mohair obtained from coloured Ankara goats is not used elsewhere due to the difficulties in dyeing, but only in local hand weavings [17].

In a study conducted by Yertürk and Odabaşıoğlu [16], it was aimed to determine various morphological and physiological characteristics of coloured mohair goats being bred in Eastern and Southeastern Anatolia Region. The study was carried out on 47 female goats aged 1.5 years old, 3 goats and 55 kids (27 males and 28 females) obtained from them within two years. As a result, it was determined that coloured Angora goats have some advantages over Angora goats in terms of live weight, mohair yield and reproductive performance, but they have potential to be improved in terms of morphological characteristics and mohair quality. In the study, the fineness values of the mohair of the shoulder, rib and thigh regions of two-year-old coloured angora goats were found to be 31.60, 35.38, 34.40 µm, respectively, and the length values were found to be 15.88, 16.75 and 14.89 cm, respectively. On the other hand, in a study carried out by Yertürk the fineness and length values of 2-year-old coloured mohair goats were found as 35.38 µm and 16.75 cm, respectively [18]. In another study, Küçük et al. found diameter, length, strength and elasticity values of coloured mohair goats as 48.44 µm, 9.64 cm, 15.86 g, 37.72%, respectively [19].

In a study conducted on 30 coloured mohair goats bred in Yüzüncü Yıl University, Faculty of Veterinary Medicine, Research and Application Farm, the relationship between transferrin genotypes and mohair characteristics was investigated. The results revealed that transferrin genotypes may affect mohair quality [20].

Beyond these studies, the literature has also investigated the effects of crossbreeding on various fibre traits. Odabaşıoğlu et al. (2003) noted that mohair yield and quality were quite low in coloured Angora goats and that improving these traits through selection would take a very long time. Therefore, short-term breeding opportunities through crossbreeding were investigated. Therefore, the effect of crossbreeding white Angora goats with coloured Angora goats on mohair quality was investigated. In their project, Odabaşıoğlu et al. (2003) found the mohair yield and efficiency to be 423 g and 74.3% in coloured angora goats and 832 g and 75.9% in crossbred F1s. In addition, the various mohair properties such as fibre fineness, length, elasticity, strength, and the ratio of kempy and medullated fibres were generally determined to be 36.8 µm, 7.40 cm, 32.37%, 8.19 g, 16.7%, and 13.08% in coloured angora goats, respectively; and 30.13 µm, 7.78 cm, 31.58%, 6.31 g, 3.35%, and 2.34% in crossbred F1s, respectively. Differences in mohair yield, fibre fineness, strength, and the ratio of kempy to medullary fibres were found to be significant ($p<0.001$) between the pure and hybrid groups. The effect of genotype on the same parameters was also found to be significant ($p<0.001$), while the effect of gender was found to be insignificant. Neither genotype nor gender had any effect on fibre length, elasticity, or mohair yield [21].

When the literature is examined, it is understood that there are few articles on the effect of pigmentation on fibre properties. Two of them are related to merino wool [22, 23], one is related to cashmere fibres and common goat guard hair [24], three are related to cashmere and yak fibres [25-27].

In this study, it is aimed to evaluate the physical and mechanical properties of mohair fibres obtained from Ankara goats raised in Siirt province of Türkiye. For this purpose, three different colours of mohair (white, brown and black) were obtained from Siirt province and the fineness, length, diameter variation, strength and elongation at break values of these fibres were analysed. Thus, the effect of pigmentation on the morphological properties of the fibres was evaluated. To the authors' knowledge, there is no comprehensive systematic study on how pigmentation affects various properties of mohair fibres. In fact, the effect of the presence of pigments in the cortical cells of protein fibres on fibre properties has not been investigated much, not only for mohair but also for other luxury animal fibres. Therefore, it is thought that this study is original and will contribute to the literature.

2. MATERIAL AND METHODS

White, brown and black coloured mohair fibres obtained from Siirt province were used in the study. Samples were taken from a randomly selected 2-years-old female goats raised in the same herd and therefore with the same care and feeding conditions. In the study, fibre samples were taken from one goat for each colour group, and all samples were collected from the same body region (the rib area) of the respective goats. Before testing, the samples were subjected to washing (only with water at 50 °C for 3 minutes > 1 g/L soda ash and 5 g/L non-ionic detergent at 50 °C for 3 minutes > 5 g/L non-ionic detergent at 50 °C for 3 minutes > rinsing with water for 3 minutes at room temperature), and then samples were dried at room temperature. They were then conditioned under standard atmospheric conditions (20±2 °C, 65±2% relative humidity). Figure 1 shows photographs related to the washing processes.

Figure 1: Photos related to the washing of mohair fibres

The washed and dried clean fibres were then subjected to various tests. All samples were tested by the same operator using the same standards and equipment. Descriptive statistics of each fibre property were examined and the results were statistically analysed. All statistical analyses were performed using Minitab19 software. First, a normality test was performed on all data according to Anderson-Darling, and since $p>0.05$ was found, it was determined that the data showed a normal distribution. Then, the equality of variances for various measurement results (fineness, length, strength, etc.) of the 3 groups (white, brown, and black) of samples was tested using the Levene test. In case the variances were equal ($p>0.05$ in Levene test); to assess whether there was a significant difference in various fibre properties depending on colour, a one-way analysis of variance (ANOVA) was performed. If statistically significant differences were detected in the ANOVA results, the Tukey multiple comparison test was applied to determine between which colours these differences occurred. In case the variances were not equal ($p<0.05$

in Levene test); to assess whether there was a significant difference in various fibre properties depending on colour, Welch's test was performed. If statistically significant differences were detected, the Games-Howell pairwise comparison test was applied to determine between which colours these differences occurred. Also, graphs were plotted to easily compare fibre colour groups with each other.

- *Fibre fineness:* Fibre fineness measurements were made with the optical fibre diameter measuring device OFDA 2000 according to IWTO (International Wool Textile Organisation) 47 standard [28]. 30 measurements were taken from each fibre colour.

- *Fibre length:* Fibre length measurements were made according to the principle of single fibre measurement according to ISO 6989:1981 [29]. The length of each fibre was measured with a ruler on a black velvet sheet. 500 measurements were taken from each fibre colour.

- *Fibre strength and elongation at break:* Fibre strength and elongation at break were measured using Prowhite-single fibre strength tester according to ASTM D3822 standard test method for strength measurements of single fibres [30]. 30 measurements were taken from each fibre colour.

- *Fibre colour:* Yellowness index and CIE L*a*b* C*h values of the samples were measured using Macbeth E700 spectral photometer (D 65/10°).
L*: Lightness-darkness value (0: ideal black, 100: ideal white)
a*: Redness-greenness value (+ more red, - more green)
b*: Yellowness-blueness value (+ more yellow, - more blue)
C*: Chroma
h: hue

3. RESULTS AND DISCUSSION

Descriptive statistics for fibre fineness, diameter variation, length, strength, and elongation at break (%) are presented in Table 1.

In our study, fineness measurements and diameter variation measurements were made after the washing processes of the samples taken from mohair goats of various colours raised in Siirt region. Welch's test results for fibre fineness (µm) data are given in Table 2.

Table 2 shows that the effect of colour on fibre fineness in mohair fibres was statistically significant ($p < 0.05$). Games-Howell pairwise comparison test was also performed to see the source of the difference and the results are given in Table 3.

When Table 3 is examined, it is seen that the fibres become coarser in the order white < brown < black. Black, brown and white fibres are in 3 different groups and the differences between them are statistically significant. In the study conducted by Gürkan Ünal and Atav [24], it was observed that pigmented fibres had higher micron values (i.e. the fibres were coarser) in both hair goats and cashmere goats. Similarly, in the study conducted by Atav and Ünal [22] and Plowman et al. [23] with white and black coloured merino wool and in the study conducted by Atav, Ergünay and Gürkan Ünal [25] with white and brown coloured yak and cashmere down fibres, it was found that coloured fibres were coarser. As it is known, the colours of pigmented fibres originate from the coloured pigments in the cortex cells forming the cortex layer [31]. The individual granules of coloured pigments are 2 µm in size [32]. The mean and variation of fibre fineness is determined by the genotype of the animal, which affects the size and growth capacity of the follicles, but can also be significantly altered by external factors, especially nutrition [25, 33].

Table 1: Descriptive statistics for various physical and technological properties of fibres

Colour		Fineness (µm)	Diameter variation (%)	Length (cm)	Strength (cN)	Elongation (%)
White	Mean	28.36	37.62	14.87	8.63	34.97
	Standard deviation	0.86	1.32	2.31	1.37	4.24
	CV%	3.02	3.51	15.51	15.82	12.12
Brown	Mean	34.03	22.41	14.95	16.07	35.4
	Standard deviation	0.60	0.16	1.89	1.45	3.37
	CV%	1.77	4.0	12.66	9.0	9.52
Black	Mean	51.64	22.09	15.41	23.16	37.7
	Standard deviation	1.61	1.87	2.10	3.10	3.68
	CV%	3.12	8.46	13.59	13.39	9.76

Table 2: Welch's test results for fineness (µm) values of mohair fibres of various colours

Source	DF Num	DF Den	F-Value	P-Value
Colour	2	52,5085	2419,30	0,000

Table 3: Games-Howell pairwise comparison test results for the fineness (µm) values of mohair fibres of various colours

Colour	N	Mean	Grouping		
Black	30	51,641	A		
Brown	30	34,034		B	
White	30	28,361			C

Fibre diameter (fineness) is often the most important factor determining the quality and price of animal fibres such as mohair. The finer the fibre, the more demanded it is and the higher its price [11]. Woollen fabric wearer comfort and response to stinging are directly related to fibre diameter and fabric handle. User trials have shown that the average fibre diameter is the most important source of stinging sensation [34].

When the local mohair obtained from Siirt province is evaluated in terms of fibre fineness, white mohair is classified as second kid (27.55-31.54 µm), brown mohair is classified as first adult (31.55-35.54 µm) and black mohair is classified as fourth adult (43.55 µm and above) according to American standards [13].

All these mentioned results can be clearly seen from "Interval Plot of Fineness versus Colour" given in Figure 2.

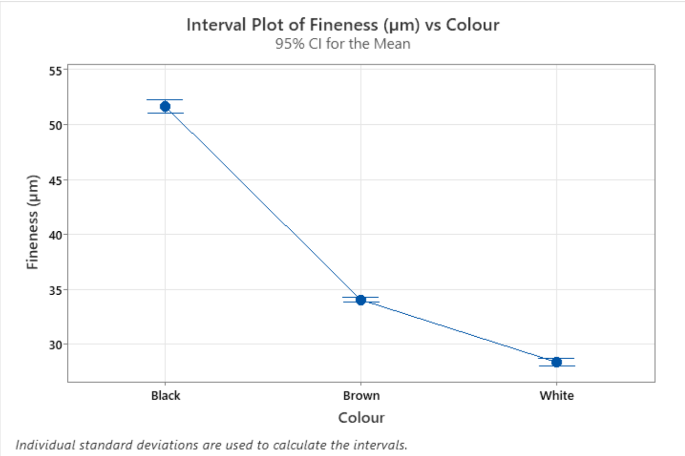

Figure 2: Interval plot of fineness versus colour

Although average fibre diameter is the most basic parameter measured, diameter uniformity (CV% of fibre diameter) is also of great importance in textiles [35]. Therefore, the diameter variation of the fibres was also measured. The results of analysis of variance for diameter variation data are given in Table 4.

Table 4: Analysis of variance results for diameter variation values of mohair fibres of various colours

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Colour	2	4725,2	2362,61	1173,35	0,000
Error	87	175,2	2,01		
Total	89	4900,4			

Table 4 shows that the effect of colour on diameter variation in mohair fibres was statistically significant ($p < 0.05$). Tukey analysis was also performed to see the source of the difference and the results are given in Table 5.

Table 5: Tukey analysis results for diameter variation values of mohair fibres of various colours

Colour	N	Mean	Grouping		
White	30	37,621	A		White
Brown	30	22,411		B	Brown
Black	30	22,094		B	Black

When Table 5 is examined, it is seen that the diameter variations of the fibres decrease in the order white > brown > black. Since black and brown coloured mohair are in the same group, the difference between them is statistically insignificant, but they are in different group with white mohair and it can be said that the difference between the diameter variation of coloured mohair and white mohair is statistically significant. All these mentioned results can be clearly seen from "Interval Plot of Diameter Variation (CV%) versus Colour" given in Figure 3. Welch's test results for fibre length (cm) data are given in Table 6.

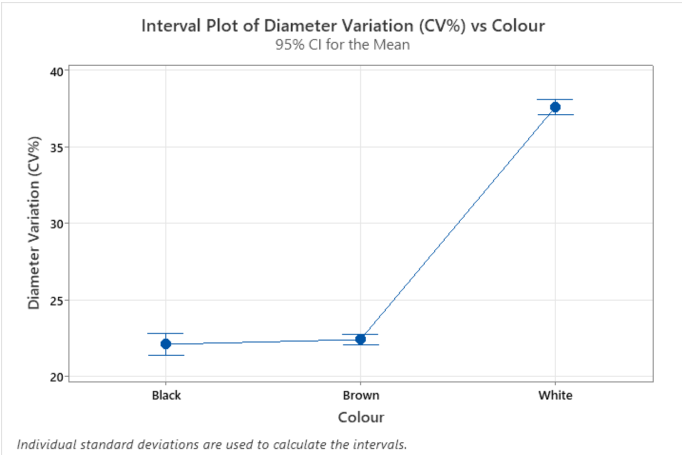

Figure 3: Interval plot of diameter variation (CV%) versus colour

Table 6: Welch's test results for length (cm) values of mohair fibres of various colours

Source	DF Num	DF Den	F-Value	P-Value
Colour	2	991,569	9,61	0,000

Table 6 shows that the effect of colour on fibre length in mohair fibres was statistically significant ($p < 0.05$). Tukey analysis was also performed to see the source of the difference and the results are given in Table 7.

Table 7: Games-Howell pairwise comparison test results for the length (cm) values of mohair fibres of various colours

Colour	N	Mean	Grouping	
Black	500	15,4116	A	
Brown	500	14,9484		B
White	500	14,866		B

When Table 7 is examined, it is seen that the length (cm) of the fibres increased in the order of white < brown < black. Brown and white fibres are in the same group and the differences between them are statistically insignificant. However, since these fibres are in separate groups with black fibre, it can be said that the difference between them in terms of length is statistically significant. In other words, black mohair is significantly longer than white and brown fibres. As it is known, in protein fibres, fine fibres are shorter and coarse fibres are longer. Therefore, it is normal that the coarser black mohair is longer than the finer white and brown mohair. All these results can be clearly seen from "Interval Plot of Length (cm) versus Colour" given in Figure 4. Welch's test results for single fibre breaking strength (cN) data are given in Table 8.

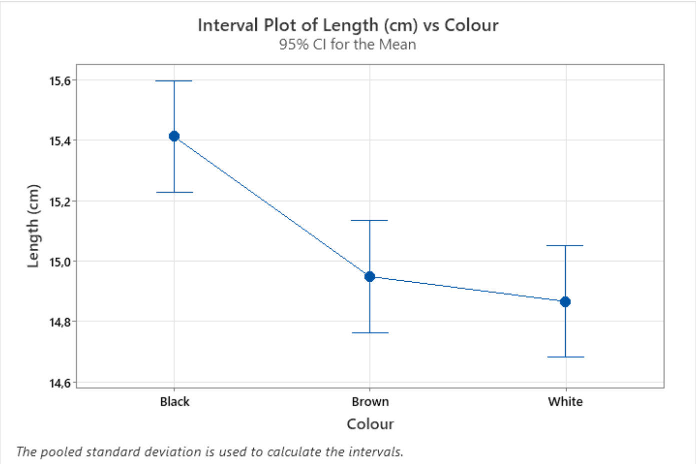

Figure 4: Interval plot of length (cm) versus colour

Table 8: Welch's test results for strength **(cN)** values of mohair fibres of various colours

Source	DF Num	DF Den	F-Value	P-Value
Colour	2	54,4072	376,96	0,000

Table 8 shows that the effect of colour on fibre fineness in mohair fibres was statistically significant ($p < 0.05$). Games-Howell pairwise comparison test was also performed to see the source of the difference and the results are given in Table 9.

Table 9: Games-Howell pairwise comparison test results for the strength (cN) values of mohair fibres of various colours

Colour	N	Mean	Grouping		
Black	30	23,160	A		
Brown	30	16,067		B	
White	30	8,630			C

When Table 9 is examined, it is seen that the strength (cN) of the fibres increases in the order white < brown < black. Black, brown and white fibres are in 3 different groups and the differences between them are statistically significant. In general, in the case of animal fibres, the force required to break the fibre, i.e. the fibre strength, increases almost linearly with the fibre cross-sectional area [35]. Therefore, it is normal that coarser black mohair is more resistant than finer white mohair. All these mentioned results can be clearly seen from "Interval Plot of Strength (cN) versus Colour" given in Figure 5.

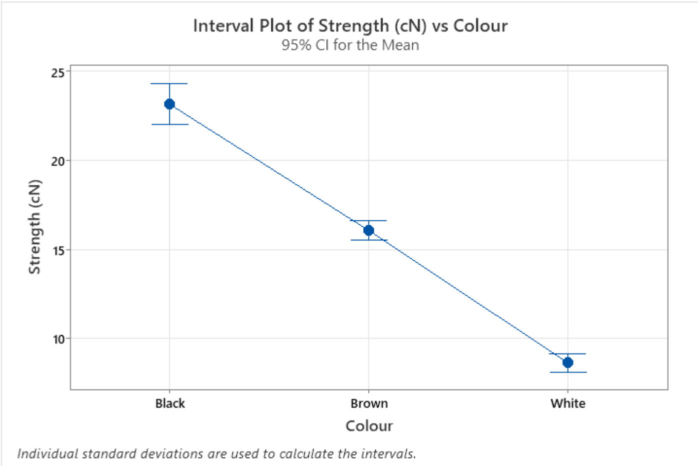

Figure 5: Interval plot of strength (cN) versus colour

Elongation at break is a result of the breaking stress of the strength. The elongation rate of the fibre at break is expressed as %. It is the percentage expression of the ratio of the amount of elongation at the breaking point to the initial length. Breaking length is a theoretical term. It is the length that allows the fibre to break with its own weight [36]. The results of analysis of variance for elongation at break (%) data are given in Table 10.

Table 10: Analysis of variance results for elongation at break (%) values of mohair fibres of various colours

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Colour	2	129,5	64,74	4,53	0,013
Error	87	1242,5	14,28		
Total	89	1372,0			

When Table 10 is examined, it is seen that the effect of colour on elongation at break in mohair fibres was statistically significant ($p < 0.05$). Tukey analysis was also performed to see the source of the difference and the results are given in Table 11. These results can be clearly seen from "Interval Plot of Strength (cN) versus Colour" given in Figure 6.

Table 11: Tukey analysis results for elongation at break (%) values of mohair fibres of various colours

Colour	N	Mean	Grouping	
Black	30	37,700	A	
Brown	30	35,400	A	B
White	30	34,967		B

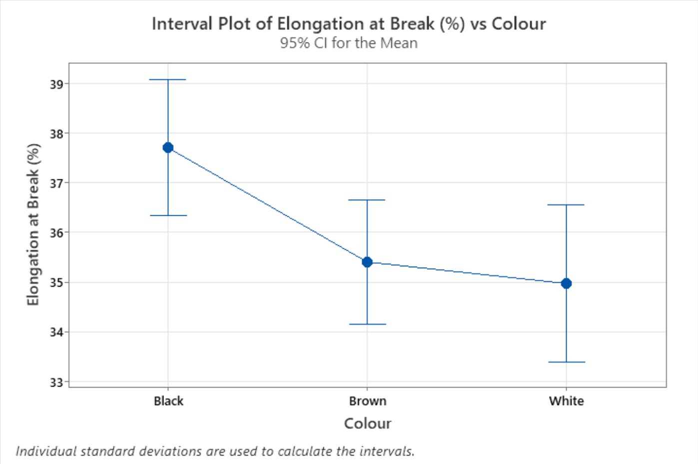

Figure 6: Interval plot of strength (cN) versus colour

Colour is an important fibre property in protein fibres. Therefore, Yellowness index and CIE L*a*b* C*h values of the fibre samples were measured by spectrophotometer and the results are given in Table 12.

When Table 12 is examined, it is seen that the L* values increase in the order of black < brown < white, indicating that this colour has lightened. Brown mohair has the highest redness-greenness (a*) value. This means that the brown colour has a red nuance. On the other hand, the yellowness-blueness (b*) values of white and brown fibres are higher than black mohair, which means that the colour has a more yellow nuance.

4. CONCLUSION

Recently, much research has been carried out on the production of naturally coloured cottons. Dyeing is one of the most costly steps among finishing processes due to high water and energy use and waste production. By using natural coloured cotton, the dyeing process is no longer necessary and textile mills can reduce their processing costs by using less water and energy. While there are many studies on the production and use of naturally coloured cotton, there is no study on the potential of using naturally coloured mohair fibres directly in textile clothing. If the utilisation potential of coloured mohair fibres can be evaluated, dark colours such as black and brown, which can be obtained with high dye consumption, can be obtained without the use of dyes, and in addition to cost savings, there will be an advantage in terms of environmental ecology due to less waste load. Apart from this, in this case, the colour of the fibre will be due to the colour pigments in the cortical cells forming the cortex layer, not the dye it takes into its structure, which will result in high wet fastness values. Considering that colours such as black, brown and grey are especially preferred in the field of woollen clothing, the fact that the production in question will be carried out without the need for dyeing will mean that the product to be obtained will be fully environmentally friendly and sustainable. This means that a product with high added value will be obtained. Thus, coloured mohair, which is normally separated into second quality and sold at low prices, will be able to find buyers at much higher prices if the necessary promotion and marketing strategies are implemented worldwide.

In the study, it was found that pigmentation had a significant effect on fibre fineness, diameter variation, fibre length and fibre strength. It was found that fibre diameter, strength and length increased, whereas diameter variation decreased in the order White < Brown < Black. Among the coloured mohair, it can be said that brown mohair is the best quality in terms of both fineness and diameter variation. Since fibre samples were collected from only one goat per colour group, the findings of this study should not be generalized to the entire regional goat population. The results presented here reflect only the characteristics of the sampled individuals and therefore represent a comparison among the three goats, each corresponding to a different colour group. In future studies, it would be beneficial to conduct investigations on larger populations within each colour group.

Table 12: Yellowness index and CIE L*a*b* C*h values of various coloured mohair fibres

Colour	Yellowness index	L*	a*	b*	C*	h
White	39.5	53.0	-2.4	11.1	11.4	77.9
Brown	68.6	31.0	5.9	12.1	13.5	63.9
Black	15.4	10.0	0.2	0.6	0.7	71.5

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