Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2022) 46: 235-247
© TÜBİTAK
doi:10.3906/vet-2105-76

Effects of age and body region on wool characteristics of Merino sheep crossbreds in Turkey

Sedat BEHREM[1], **Sabri GÜL**[2,*]

[1]Department of Genetic, Faculty of Veterinary Medicine, Aksaray University, Aksaray, Turkey

[2]Department of Animal Science, Agricultural Faculty, Hatay Mustafa Kemal University, Antakya-Hatay, Turkey

Received: 31.05.2021 • **Accepted/Published Online:** 24.01.2022 • **Final Version:** 25.04.2022

Abstract: Aim of this study was to comparatively investigate the wool characteristics of Central Anatolian Merino, Karacabey Merino and Ramlıç sheep, which are common crossbred sheep breeds in Turkey. A total of 360 wool samples were equally collected from the shoulder, rib, and rump of each lamb (3–6 months-age), yearlings (1–1.5-year age), primiparous ewes (2–2.5-year age) and multiparous ewes (3–3.5-year age) were used for analysis. Each sample was analyzed to determine fibre diameter, length, clean fleece yield, elasticity, and strength. Also, live weight after shearing and greasy fleece weights were recorded for each animal. Statistical analysis of this study was performed using SPSS software. Normality hypothesis tested using the Shapiro–Wilk test. Homogeneity of the variance for each trait was tested with the Levene's test. Descriptive statistics of the traits were given as mean ± standard error. Observed means for greasy fleece weight were 3.6 ± 0.09 kg, 2.5 ± 0.09 kg, and 2.2 ± 0.08 kg for Karacabey Merino, Central Anatolian Merino and Ramlıç sheep, respectively. Average diameter, length, clean fleece yield, elasticity, and strength measurements of Karacabey Merino were 23.9 ± 0.11 μ, 59.2 ± 0.64 mm, 56.2 ± 0.35%, 20.2 ± 0.23 cN / tex, and 12.6 ± 0.09 cN / tex, whereas 24.7 ± 0.12 μ, 50.6 ± 0.71 mm, 55.2 ± 0.60%, 21.6 ± 0.23 cN / tex, 13.8 ± 0.14 cN / tex in Central Anatolian Merino and 24.1 ± 0.12 μ, 53.2 ± 1.05 mm, 62.9 ± 0.53%, 22.3 ± 0.26 cN / tex, 13.4 ± 0.12 cN / tex were observed in Ramlıç sheep, respectively. This study suggests that observed wool characteristics for each of three crossbreds were within the standard range of the textile industry. Therefore, all three crossbreds were suggested to be considered for the development of new agricultural policies and increasing breeder's awareness to reintroduce these crossbreds in the textile industry.

Keywords: Merino sheep, wool characteristics, body region, age of sheep

1. Introduction

Even though sheep farming has been popular for also wool production in many countries, it has been carried out mostly for the purpose of meat and milk production in Turkey. Australia and China are two leading countries that control industrialized wool production in the world with 24% and 15% of the total production, respectively. Those countries are followed by New Zealand with 10%, South Africa with 2.6%, Argentina, and England with 2% [1]. Merino sheep, which is best known for their fine and high-quality fleece, have a special place in sheep breeding. The indigenous sheep breeds that are raised in Turkey have coarse and mixed fleece. The quality of the fleece produced from these sheep is mostly suitable for use in the blanket, quilt, and carpet industry [2], but unfortunately not for apparel and high-quality textile products. Production preferences moved towards the use of synthetic fabrics instead of wool fibres within the last half-century. As a result, wool production gradually lost its importance for breeding programs conducted in Turkey. Merino crossbreeding studies were carried out in order to provide high-quality fleece needed by the Turkish textile industry during the 1950s. Initially, these studies partially fulfilled their goals. However, it has deviated from its main goal due to the changes in the requirements of modern industry, nowadays. The breeds used for wool production back then, such as Karacabey Merino, Central Anatolian Merino, and Ramlıç sheep, were started to be bred for meat production rather than wool production. Although it is underrated, the production of wool for textile purposes still continues with a small number of volumes.

Data presented by TUIK (Turkish Statistical Institute) in 2019 showed that there were 34.199.467 heads of native and 3.076.583 heads of Merino sheep and its crossbreds in Turkey. The annual wool production from native sheep and Merino, together with its crossbreds, were 61.134 tons and 9.453 tons, respectively [3]. To date, various studies have been conducted to determine the fleece characteristics of native and crossbred sheep produced in Turkey [4–13]. In recent years, the National Community-based Small Ruminant Breeding Programme provoked awareness about the potential importance of fleece production of

* Correspondence: sabrigul@gmail.com

Merino crossbreds in Turkey. However, up-to-date studies investigating the effects of certain environmental factors comparatively among different Merino crossbreds are quite scarce in the literature.

The most important fleece quality traits in sheep are being greasy, having clean yield in addition to fibre diameter, length, strength, and elasticity. These traits were suggested to show variation regarding breed, the age of the animal, and body region of sampling [13–18].

Therefore, the present study aimed to determine characteristics of wool collected from Central Anatolian Merino, Karacabey Merino, and Ramlıç sheep, as well as investigate the effects of age and body region of sampling on these properties.

2. Materials and methods

2.1. Material

Animal materials used in the study were Central Anatolian Merino (CAM) (85% German Meat Merino and 15% Akkaraman) raised in Ankara, Ramlıç Sheep (R) (65–70% Rambouillet and 30–35% Daglic) raised in Eskişehir and Karacabey Merino (KM) (95% German Meat Merino and 5% Kıvırcık) raised in Balıkesir province. Four trial groups of 30 animals each were formed including female lambs (3–6 months old), yearling sheep (1–1.5 years old), primiparous (2–2.5 years) and secundiparous sheep (3–3.5 years and over) for the present study. Wool samples of all animals were taken from the three different regions (i.e., shoulder, rib, and rump). This study was approved by Hatay Mustafa Kemal University Animal Ethics Committee with an application batch number of HMKU – HADYEK – 2018 / 3–4.

2.2. Method

In this study, randomly selected animals from three different crossbreds were sheared for wool between May and June. The shearing process of the animals was carried out on clean, shadowed, and flat ground with sufficient light by experienced staff with an automatic shearing machine. The wool weighing was carried out with a 10 g sensitive balance. Following weighing, approximately 100 g of wool samples were taken from 3 different body regions of each animal, namely shoulder, rib, and rump. These samples were packed in plastic bags and labelled so that all information (i.e., age, breed, and body region) of each sample could be seen clearly. The packed samples were kept in a suitable environment until the day of analysis. For all experimental animals, body weight was measured right after shearing with a 100 g sensitive balance.

In the study, the effects of breed and age group on greasy wool weight and body weight after shearing were investigated in respect to the breed and age groups. Furthermore, efficiency for animals was estimated and, fibre diameter, length, elasticity, and strength analyses were performed on samples taken from each of shoulder, rump and rib areas. For those analyses, a small amount of sample was taken from the greasy wool after shearing and weighed on a sensitive scale. This wool was then washed with 3 units of powder soap, 0.5 units of powder soda in warm water, and rinsed to remove the foreign material, grease, and dirt. Later, the wool samples were left to be dried in the oven (i.e., in Immersion Conditioning Oven) at 105 °C for 6 h. Efficiency (%) was then calculated by using the weights of the samples weighed in sensitive scales with aid of the following formula.

Efficiency% = (weight of clean wool + 0.14 * weight of clean wool / weight of greasy wool) * 100

For the analysis of fibre length, the fibres were first aligned and straightened from the one end and placed into the OFDA 2000 device (i.e., optical fibre diameter analyser) for measuring. The fibre samples placed in the OFDA 2000 were automatically measured by the optical measuring tool of the instrument in millimetres (mm).

Fibre Diameter was determined by the USTER OFDA 100 (i.e., optical fibre diameter analyser) device, which can measure 4,000–5,000 fibres at a time. Clean fibre samples were chopped at a certain rate and placed on a lamella in the measurement unit of the device for measuring according to optical principles and giving the resulting fibre diameter measurements in micron.

Fibre elasticity and strength analyses were performed in the Fleece Mohair Laboratory of the International Centre for Livestock Research and Training in Turkey by the FAFEGRAPH M 'Single Fibre Tensile Tester' device. A single fibre that is attached to the arms moving by the air pressure from a compressor was pulled gradually. The fibre can stretch and resist to rupture until some point, where the amount of elongation at the moment of rupture is named as "elasticity", and how much force it resisted was expressed as the "strength" as cN / tex.

2.3. Statistical analyses

SPSS v21.0 software for Windows was used for the statistical analyses in the present study. Normality assumption was tested by Kolmogorov–Smirnov and Shapiro–Wilk test. Homogeneity of variances was tested with Levene's test. DUNCAN multiple comparison tests were used to compare the groups with the statistical difference between them as a result of variance analysis. The relationships between the variables were determined according to Pearson correlation analysis. In all statistical analyses, $p < 0.05$ values were considered statistically significant. Finally, means of the observations were given with their relevant mean ± standard errors [19].

3. Results

The results for live weights and greasy fleece weights of Merino crossbreds are presented in Table 1.

The results clearly indicate that means for live weight and raw fleece weight were increased in merino crossbreds, as the animals get older ($p < 0.01$).

Table 2 shows the least square means (LS) according to the breed, age, and body region of the sheep.

When the results examined for the fleece properties based on breed (Table 2), the finest fleece was in KMs, and the thickest in CAM ($p < 0.01$). The average diameter value (24.1 ± 0.12 µ) in Ramlıç sheep was found to be similar to KM (23.9 ± 0.11 µ) ($p > 0.05$), while a significant difference was recorded in CAMs (24.7 ± 0.12 µ) ($p < 0.01$).

While the longest fleece length (59.2 ± 0.64 mm) was in KM, the shortest fleece length (50.6 ± 0.71 mm) was in CAMs, among which the difference was found to be statistically significant ($p < 0.01$). The fleece in Ramlıç sheep was classified as medium length. A statistical difference in terms of medium fleece length was found between Ramlıç sheep and other breeds ($p < 0.01$). The physical properties of fleece were affected by the breeds as is the case for the other traits ($p < 0.01$).

The highest rate in terms of fleece yield was in Ramlıç sheep. While KM and CAM sheep showed similar results (56.2 ± 0.35% vs 55.2 ± 0.60%; $p > 0.05$) in terms of fleece yield, there was a significant difference between these two breeds and Ramlıç sheep ($p < 0.01$). Elasticity values showed differences between the three breeds ($p < 0.01$). The highest value (%) was in Ramlıç sheep (22.3 ± 0.26) and the lowest value (%) was in KM (20.2 ± 0.23) in terms of elasticity.

Despite the fact that CAM and Ramlıç are similar to each other in terms of strength properties (i.e., 13.8 ± 0.14 cN / tex vs 13.4 ± 0.12 cN / tex, respectively), a statistical difference has been found ($p < 0.01$). The fleece strength in KM merino was statistically lower than those other two breeds ($p < 0.01$). Fleece with a diameter of 10–30 µ is mostly preferred in the textile industry. The diameter values of samples got thicker as the animal got older, which was statistically significant ($p < 0.01$). Fleece length also differed depending on age ($p < 0.01$). While the shortest fleece length was in the lamb group (37.4 ± 0.62 mm), the longest fleece was measured in the yearling sheep (65.4 ± 0.90 mm). These differences between age groups were also statistically significant ($p < 0.01$). The reason why the fleece is long in the yearling is that the animals were not sheared during the lambing period. The fleece yield value was the highest in lambs, and there was no effect of age among other age groups ($p > 0.05$). Fleece elasticity value changed as the age got older in sheep ($p < 0.01$). If the sheep that have given birth once are not taken into account, the elasticity changes depending on the age. Among the age groups, the strength also differed depending on the age, as is the case for elasticity, and the differences between the groups were statistically significant ($p < 0.01$).

In this study, it was determined that the examined parameters of fleece were affected by the sampling region on the animal body ($p < 0.01$). Fibre diameter value was very similar in the shoulder and rib area of the body ($p > 0.05$), and a higher value was obtained in the thigh region ($p < 0.01$). The length was similar in all three regions, and no statistical difference was found between the groups ($p > 0.01$). While the fleece yield is similar between rump and rib ($p > 0.05$), the difference between these two regions and the shoulder area was significant ($p < 0.01$). While there was a similarity between the shoulder and rump region in terms of elasticity ($p > 0.05$), the rib region was higher than the other regions ($p < 0.01$). The strength value of fleece was different in all 3 regions, and a statistical difference was also found between all body parts ($p < 0.01$).

On the other hand, Table 3 shows the LS means according to the age and body region of the KM.

As shown in Table 3, fleece characteristics in KM are different in terms of the age and body parts where they are

Table 1. Live weight after shearing and greasy fleece weight (kg) of Merino crossbreds.

Traits	Age groups	KM	CAM	Ramlıç	p
Live weight	Lamb	43.5 ± 3.88^{c}	37. 1± 3.75^{b}	30.8 ± 3.05^{a}	0.000
	Yearling	65.8 ± 7.75^{b}	65.5 ± 6.30^{b}	45.5 ± 4.61^{a}	0.000
	Primiparous	63.7 ± 5.11^{b}	69.6 ± 5.23^{c}	50.0 ± 7.50^{b}	0.000
	Multiparous (2 ≥)	71.5 ± 6.31^{b}	78.1 ± 6.19^{c}	50.4 ± 4.74^{a}	0.000
Greasy wool yield	Lamb	2.3 ± 0.52^{c}	1.2 ± 0.26^{b}	0.9 ± 0.12^{a}	0.000
	Yearling	4.0 ± 0.71^{b}	2.9 ± 0.62^{a}	2.9 ± 0.55^{a}	0.000
	Primiparous	4.1 ± 0.65^{c}	3.0 ± 0.55^{b}	2.5 ± 0.50^{a}	0.000
	Multiparous (2 ≥)	3.7 ± 0.63^{c}	2.9 ± 0.58^{b}	2.4 ± 0.52^{a}	0.000
	General	3.6 ± 0.09^{c}	2.5 ± 0.09^{b}	2.2 ± 0.08^{a}	0.000

* Letters on the same line shows statistical differences.

Table 2. LS means and standard errors of Merino crossbred wool quality traits by breed, age, and body region.

Breeds	Diameter (μ)	Length (mm)	Efficiency (%)	Elasticity (%)	Tenacity (cN / tex)
KM	23.9 ± 0.11[a]	59.2 ± 0.64[c]	56.2 ± 0.35[a]	20.2 ± 0.23[a]	12.6 ± 0.09[a]
CAM	24.7 ± 0.12[b]	50.6 ± 0.71[a]	55.2 ± 0.60[a]	21.6 ± 0.23[b]	13.8 ± 0.14[c]
Ramlıç	24.1 ± 0.12[a]	53.2 ± 1.05[b]	62.9 ± 0.53[b]	22.3 ± 0.26[c]	13.4 ± 0.12[b]
p	0.000	0.000	0.000	0.000	0.000
Age					
Lamb	23.8 ± 0.13[a]	37.4 ± 0.62[a]	62.2 ± 0.52[b]	19.8 ± 0.28[a]	12.9 ± 0.11[a]
Yearling	24.2 ± 0.14[ab]	65.4 ± 0.90[d]	57.8 ± 0.52[a]	21.8 ± 0.27[b]	12.8 ± 0.13[a]
Primiparous	24.4 ± 0.14[bc]	55.4 ± 0.62[b]	56.2 ± 0.67[a]	21.2 ± 0.29[b]	13.4± 0.14[b]
Multiparous (2 ≥)	24.6 ± 0.14[c]	58.1 ± 0.80[c]	56.5 ± 0.69[a]	22.7 ± 0.26[c]	13.9 ± 0.15[c]
p	0.000	0.000	0.000	0.000	0.000
Body region					
Shoulder	23.6 ± 0.11[a]	54.3 ± 0.86	59.6 ± 0.51[b]	20.9 ± 0.25[a]	12.6 ± 0.11[a]
Ribs	23.8 ± 0.11[a]	54.2 ± 083	56.7 ± 0.52[a]	22.2 ± 0.25[b]	13.0 ± 0.11[b]
Rump	25.3 ± 0.12[b]	54.4 ± 0.85	58.1 ± 0.58[a]	21.1 ± 0.22[a]	14.2 ± 0.13[c]
p	0.000	0.988	0.001	0.000	0.000

* Letters on the same column shows statistical differences.

Table 3. LS means and standard errors of wool quality traits by age and body region of KM.

Karacabey Merino					
Groups	Diameter (μ)	Length (mm)	Efficiency (%)	Elasticity (%)	Tenacity (cN / tex)
Lamb	23.8 ± 0.19[b]	47.3 ± 0.87[a]	59.6 ± 0.67[c]	18.8 ± 0.43[a]	12.9 ± 0.15[b]
Yearling	23.9 ± 0.22[b]	65.2 ± 1.04[c]	56.7 ± 0.55[b]	21.3 ± 0.50[b]	12.4 ± 0.16[a]
Primiparous	23.2 ± 0.21[a]	56.4 ± 0.80[b]	52.0 ± 0.64[a]	19.3 ± 0.43[a]	12.2 ± 0.17[a]
Multiparous (2 ≥)	24.7 ± 0.22[c]	66.1 ± 1.21[c]	57.0 ± 0.68[b]	21.2 ± 0.43[b]	13.1 ± 0.21[b]
p	0.000	0.000	0.000	0.000	0.000
Shoulder	23.4 ± 0.16[a]	59.6 ± 1.19	58.4 ± 0.63[b]	19.2 ± 0.43[a]	12.0 ± 0.14[a]
Ribs	23.5 ± 0.18[a]	59.5 ± 1.09	54.6 ± 0.57[a]	21.4 ± 0.41[b]	12.4 ± 0.12[b]
Rump	24.8 ± 0.20[b]	58.6 ± 1.05	55.6 ± 0.56[a]	20.0 ± 0.33[a]	13.5 ± 0.17[c]
p	0.000	0.762	0.000	0.000	0.000
Overall	23.9 ± 0.11	59.2 ± 0.64	56.2 ± 0.35	20.2 ± 0.23	12.6 ± 0.09

* Letters on the same column shows statistical differences.

collected, and these differences are statistically significant ($p < 0.01$). Within the age groups, the finest fleece was in primiparous sheep, and the longest fleece was in multiparous (i.e., 2 and more lambing) ($p < 0.01$).

Table 4 shows the LS means according to the age and body region of the CAM.

Table 4 indicates that the means of the diameter, length, yield, and strength in the Central Anatolian Merino are not affected by age except for the lambs ($p > 0.05$). In terms of these characteristics, the results were statistically significant between lambs and other ages ($p < 0.01$). There were, however, no statistical differences in terms of the means of the elasticity among the levels of age ($p > 0.05$).

Table 5 shows the means of LS according to the age and body region of the Ramlıç.

The mean fleece characteristics of Ramlıç Sheep were statistically different between different age groups as in the other two breeds ($p < 0.01$).

Correlations between the observations in Karacabey Merino were given in Table 6.

Accordingly, a significant positive correlation was found between age and live weight, greasy fleece weight, length, and elasticity values in Karacabey merino ($p < 0.01$). The weight of the greasy fleece changed depending on the live weight, as expected ($r = 0.638$), and the length and elasticity values exhibited a positive correlation depending on the live weight ($p < 0.01$). A positive relationship was found between fibre diameter, strength, and yield. ($p < 0.01$). The correlation between fleece length and elasticity was obtained as $r = 0.253$, and a positive correlation ($r = 0.241$) was found between fleece elasticity and strength ($p < 0.01$).

The correlations between wool properties in CAM sheep are given in Table 7.

Correlation between age and live weight in the CAM was determined as $r = 0.549$, with greasy fleece $r = 0.265$,

Table 4. LS means and standard errors of wool quality traits by age and body region of CAM.

Central Anatolian Merino (CAM)					
Groups	Diameter (μ)	Length (mm)	Efficiency (%)	Elasticity (%)	Tenacity (cN / tex)
Lamb	23.8 ± 0.26[a]	35.4 ± 0.87[a]	60.5 ± 1.04[b]	19.9 ± 0.41[a]	13.0 ± 0.24[a]
Yearling	25.1 ± 0.22[b]	56.3 ± 1.10[b]	53.5 ± 1.08[a]	22.8 ± 0.44[b]	13.9 ± 0.26[b]
Primiparous	24.9 ± 0.25[b]	55.8 ± 1.06[b]	52.8 ± 1.04[a]	21.1 ± 0.49[a]	13.8 ± 0.29[b]
Multiparous (2 ≥)	25.0 ± 0.23[b]	55.0 ± 1.21[b]	54.0 ± 1.43[a]	22.6 ± 0.46[b]	14.4 ± 0.29[b]
p	0.000	0.000	0.000	0.000	0.005
Shoulder	24.2 ± 0.19[a]	49.1 ± 1.15	55.7 ± 0.99	21.3 ± 0.40	13.2 ± 0.22[a]
Ribs	24.1 ± 0.20[a]	51.6 ± 1.25	54.0 ± 1.05	22.1 ± 0.44	13.4 ± 0.20[a]
Rump	25.8 ± 0.22[b]	51.2 ± 1.27	56.0 ± 1.07	21.3 ± 0.37	14.8 ± 0.26[b]
p	0.000	0.294	0.351	0.231	0.000
Overall	24.7 ± 0.12	50.6 ± 0.71	55.2 ± 0.60	21.6 ± 0.23	13.8 ± 0.14

* Letters on the same column shows statistical differences.

Table 5. LS means and standard errors of wool quality traits by age and body region of Ramlıç.

Ramlıç					
Groups	Diameter (μ)	Length (mm)	Efficiency (%)	Elasticity (%)	Tenacity (cN / tex)
Lamb	23.8 ± 0.20[ab]	31.1 ± 0.65[a]	66.1 ± 0.74[b]	20.5 ± 0.56[a]	12.9 ± 0.18[a]
Yearling	23.4 ± 0.23[a]	74.5 ± 1.78[c]	63.2 ± 0.68[b]	21.3 ± 0.46[a]	12.2 ± 0.21[a]
Primiparous	25.0 ± 0.23[c]	54.1 ± 1.28[b]	63.8 ± 1.27[b]	23.3 ± 0.51[b]	14.2 ± 0.23[b]
Multiparous (2 ≥)	24.1 ± 0.25[b]	54.1 ± 1.28[b]	58.6 ± 1.29[a]	24.2 ± 0.42[b]	14.1 ± 0.26[b]
p	0.000	0.000	0.000	0.000	0.000
Shoulder	23.3 ± 0.19[a]	54.4 ± 1.84	64.8 ± 0.76[b]	22.0 ± 0.44	12.6 ± 0.18[a]
Ribs	23.7 ± 0.18[a]	51.7 ± 1.74	61.4 ± 0.85[a]	23.0 ± 0.45	13.1 ± 0.20[a]
Rump	25.3 ± 0.20[b]	53.6 ± 1.86	62.6 ± 1.11[ab]	22.0 ± 0.43	14.4 ± 0.21[b]
p	0.000	0.555	0.032	0.209	0.000
General	24.1 ± 0.12	53.2 ± 1.05	62.9 ± 0.53	22.3 ± 0.26	13.4 ± 0.12

* Letters on the same column shows statistical differences.

Table 6. Correlations between body weight and some fleece characteristics in Karacabey Merino Crossbred.

Traits	LW	GW	Ef	D	L	El	T
Age	0.486**	0.239*	–0.199**	0.103	0.417**	0.130*	0.046
LW		0.638**	–0.160	0.160	0.339**	0.250**	0.134
BR			0.239**	0.022	–0.003	0.214**	0.105
GW			–0.213**	0.086	0.171	0.147	0.139
Ef				0.167**	–0.016	0.094	0.178**
D					- 0.025	0.036	0.596**
L						0.253**	–0.077
El							0.241**

LW, Live Weight; BR, Body Region; GW, Greasy Weight, Ef, Efficiency; D, Diameter; L, Length; El, Elasticity, T, Tenacity; *p < 0.05; **p < 0.001.

Table 7. Correlations between body weight and some fleece characteristics in CAM.

Traits	LW	GW	Ef	D	L	El	T
Age	0.549**	0.265**	–0.197**	0.162**	0.487**	0.164**	0.173**
LW		0.763**	–0.213	0.145	0.456**	0.053	0.039
BR			–0.060	-0.012	0.078	0.077	0.033
GW			–0.222*	0.106	0.237**	–0.018	0.143
Ef				0.247**	0.003	0.135*	0.270**
D					0.329**	0.118*	0.582**
L						0.339**	0.335**
El							0.427**

LW, Live Weight; BR, Body Region; GW, Greasy Weight, Ef, Efficiency; D, Diameter; L, Length; El, Elasticity, T, Tenacity; *p < 0.05; **p < 0.001.

with fibre diameter r = 0.162, fleece length as r = 0.487, with elasticity as 0.164, with strength as r = 0.173. A negative value (r = –0.197) was found between age and fleece yield (p < 0.01). It was determined, that there was a positive correlation between age and live weight (r = 0.549), greasy fleece (r = 0.265), diameter (r = 0.162) length (r = 0.487), elasticity (0.164), strength (r = 0.173) (p < 0.01), while a negative correlation (r = –0.197) was found between age and fleece yield (p < 0.01) of Central Anatolian Merino. A positive correlation was found between body weight and greasy fleece weight as well as fleece length (p < 0.01), and no significant correlation was observed between body area and fleece properties (p > 0.05). There was a negative correlation (r = 0.222) between greasy fleece yield and efficiency, and a positive correlation between fleece length and efficiency (p < 0.01). A positive correlation was found between fleece yield and diameter, elasticity and strength (p < 0.01). In this study, it is seen that there is a significant positive correlation between fibre diameter and length, elasticity, and strength (p < 0.01), between length, elasticity and strength (p < 0.01), and between elasticity and strength in CAM (p < 0.01).

Correlation values were determined for all fleece characteristics obtained from Ramlıç sheep are given in Table 8.

As indicated in the table (Table 8), a negative correlation was found between body regions and fleece yield (p < 0.01). It was calculated that there was a strong positive correlation (p < 0.01) between fibre diameter obtained from Ramlıç sheep and elasticity (r = 0.114) and strength (r = 0.665). There is also a strong correlation (r = 0.397) between elasticity value and strength (p < 0.01). It was determined that there is a positive correlation (r = 0.379) between age and live weight in Ramlıç sheep (p < 0.01). In addition, there is a significant positive correlation between age and traits that are fleece yield, fibre diameter, length,

Table 8. Correlations between body weight and some fleece characteristics in Ramlıç sheep.

Traits	LW	GW	Ef	D	L	El	T
Age	0.379**	0.131	–0.239**	0.134*	0.259**	0.302**	0.286**
LW		0.767**	–0.133	0.239**	0.348**	0.125	0.132
BR			–0.136**	0.071	–0.056	0.081	0.093
GW			–0.088	0.427**	0.099	0.080	0.297**
Ef				0.129*	0.040	0.029	0.078
D					0.075	0.114**	0.665**
L						0.133*	0.042
El							0.397**

LW, Live Weight; BR, Body Region; GW, Greasy Weight, Ef, Efficiency; D, Diameter; L, Length; El, Elasticity, T, Tenacity; *p < 0.05; **p < 0.001.

elasticity, and strength ($p < 0.01$). Correlation values were observed as r = 0.767 between live weight and greasy fleece weight, r = 0.239 between diameter and r = 0.348 between length in Ramlıç sheep ($p < 0.01$). The correlation value between body weight and elasticity as well as strength was found to be statistically non-significant ($p > 0.05$).

4. Discussion

In the present study, live weight after shearing, greasy fleece weight and some fleece quality parameters such as fineness, length, efficiency, elasticity, and tenacity were investigated in CAM, KM and Ramlıç breeds, which are merino crosses. In addition, greasy fleece weight and fleece quality parameters were evaluated according to body regions (shoulder, ribs, and rump) and age (lamb, yearling, primiparous and multiparous) for each breed.

The live weights after shearing were statistically different ($p < 0.01$) between breeds and between age groups. Although average live weights were found to be close in CAM and KM, this value was found to be relatively lower in Ramlıç. Similar to the literature reviews, the live weights after shearing were found to be different between the breeds [8–13,20–30]. This difference is thought to be due to the genetic background of different breeds and also different environmental conditions in which the breeds are located. The difference in the average greasy fleece weight among age groups was statistically significant in KM and CAM sheep, while the difference in Ramlıç sheep was insignificant in the current study. The greasy fleece weight in KM and CAM sheep was found to be no different in primiparous and multiparous groups. Also, the general averages of greasy fleece weight were 3.6 ± 0.09, 2.5 ± 0.09 and 2.2 ± 0.08 in KM, CAM and Ramlıç sheep, respectively. As in our current study, it has been reported that age and breed factors are effective on greasy fleece weight in several research [8–13, 20–30]. In the study carried out by Hatcher et al. [24] on merino sheep, it was reported that the best yield in greasy fleece weight was obtained from sheep up to 3 years old. In another study by Sahoo and Soren [31], it was reported that the increase in sheep age had a negative effect on the greasy fleece yield due to the difficulties in meeting the basic needs such as nutrition in elders. Similarly, Khan et al. [32] reported that feeding had a direct effect on fleece amount, morphology and chemical structure. Considering that the animals in the lamb group were not given enough time until shearing in our current study, it seems that the highest yield was obtained in the groups (yearling and primiparous) up to 3 years of age. Therefore, age is an important parameter to consider in terms of fleece quality in sheep breeding for wool production. These results support that the greasy fleece yield after shearing is in parallel with the results reported by other researchers.

The fibre diameter analyses were evaluated in terms of breed, age groups, and body regions; it was observed that the thinnest fibre was in KM sheep, lamb, and shoulder region, respectively (Table 2). In the evaluation of fibre length in terms of these three factors, there was a statistical difference among breed and age groups ($p < 0.01$), but no difference was found among body regions ($p > 0.05$). The longest fibre was found in KM breed sheep and in the yearling. Here, the main reason for this difference in the yearling is that the shearing period is 12 months in the primiparous and multiparous animals, while it is 18 months in the yearling. Therefore, for a meaningful evaluation in age groups in terms of fibre length, the difference between primiparous and multiparous animals in equal conditions was taken into account. It is seen that the fibre length is longer in multiparous animals. In the evaluation made in terms of wool efficiency, the factors of breed, age groups, and body regions were found to be statistically significant and Ramlıç sheep's lamb and shoulder region were found to be the highest. In the elasticity analysis, Ramlıç sheep, multiparous animals, and rib region elasticity were found to be the highest. Lastly, CAM, multiparous animals, and rump region were found to be the highest in the evaluation of breed, age and body regions in terms of tenacity.

As can be understood from the paragraph summarized above, fleece quality parameters vary considerably according to the breed, age, and body region of the animals. In the literature studies carried out, it has been reported that there are differences in terms of quality in fleeces taken from different body parts of animals in different breeds and ages, which are similar to the results in our study [7,15–17,24,32–38].

The breed is an important factor for wool quality parameters. In our study, the fibre diameters of KM, CAM and Ramlıç were found to be 23.9 μ, 24.7 μ, and 24.1 μ, respectively. The textile industry needs fleece with a diameter of 18–23 μ, and merino sheep provide this fineness [39–42]. In the same breed, several research were conducted, and the fibre diameter was found to be 28.67 μ, 23.5–20.6 μ, 20.6–26.4 μ and 22.88 μ by Atav et al. [43], Sönmez [44], Harmancıoğlu [45] and Erdem [46], respectively.

The fleece length is the second most important factor in the textile industry after fineness. This feature changes depending on the shear number, genetics, and nutrition, and it is desired that the most suitable fleece for the textile industry should be below 150 mm [38]. The fleece length in KM, CAM, and Ramlıç was found to be 59.2 mm, 50.6 mm, and 53.2 mm, respectively in the current study. The length of fleece in Karacabey merinos was determined as 8.9 cm by Atav et al. [43] and in the range of 9–12 cm by Erdem [47].

Mean fibre parameters are influenced by the primary (P) follicle ratio to secondary (S). The P:S ratio is genetically and nutritionally controlled and varies between sheep breeds [48]. Different breeds have adapted to different geographical regions with different climatic conditions and have survived by providing the most appropriate gene-environment interaction. This gene-environment interaction is expressed differently in each breed, and ultimately there are morphological differences between breeds. Ansari-Renani et al. [33] reported that different photoperiod has the potential to change neuro-secretory rhythms through the pineal gland and affects the initiation of hair growth, follicle activity and eventually the quality such as fibre, length, tenacity, and elasticity. Additionally, Champion, and Robards [34] reported that primary and secondary follicles, which directly affect fleece quality, are directly effective on the amount and quality of feed consumption, and this creates significant differences in the quality of fleece among breeds. As a result, it can be said that the reason for the wool quality differences among the breeds are that each breed was raised in a different geographical region and was subjected to different conditions as well as feeding strategies.

The age factor has an important effect on the wool characteristics. It had a statistically significant effect on the fleece quality parameters ($p < 0.01$). Previous studies and our current study have revealed that the quality of fleece depends on age [7,15–17,24,32-38]. Yüceer et al. [49] found that the length of the fleece was significantly affected by age in Acıpayam sheep. In addition, Zinalabidin [50] in Karadi sheep found that age affects the length, elasticity, strength, diameter, and yield of fleece. Moreover, Aziz and Al-Omary [51] found that age has an effect on fibre diameter in Hamadani sheep. Usually, the fibre diameter of the fleece quality features is fine until the age of 3 to 4 years, while the quality features decrease at later ages. The main factor that affects the quality of the fibre structure is the physical situation of the sheep. Primary follicle and seconder follicle formation in the skin directly dominate the features that determine the quality of fibre structure. These follicles change depending on metabolism with age and may reduce the quality of the fleece [32–38]. These changes result in differences in the amount and the quality characteristics of the fleece. The quality of the fleece tends to deteriorate gradually depending on age.

The body region of the merino crossbred where the wool sample is taken from the animal is also an important factor that affects some characteristics of the fleece ($p < 0.01$). As can be seen from Table 2, the thinnest fibre is obtained from the shoulder area and the thickest fibre is obtained from the rump area. There was no difference in length between the body regions ($p > 0.05$), but statistical importance was determined in terms of yield, elasticity and strength values ($p < 0.01$; 0.05). Sönmez [44], Henderson et al. [52]; Sumner et al. [53], Tuncer [54] and Boztepe [55] reported that the fleece gets thicker as it goes from the shoulder to the rump area. In the present study, the fibre diameters were found to be 23.6 μ, 23.8 μ and 25.3 μ for shoulder, rib, and rump, respectively. Uzun Kara [10] found a fibre diameter of 23.86 μ in the shoulder area, 24.31 μ in the rib area, and 24.75 μ in the rump area in Karacabey Merino; Tuncer and Cengiz [56] found the fibre diameter as 25.16 μ in Anatolian merino and 30.99 μ in Akkaraman sheep; Arık et al. [57] reported the diameter values of Anatolian merino as 23.19 μ in the shoulder, 23.07 μ in the ribs, and 23.46 μ in the rump region. In addition, Yılmaz and Denk [22] suggested fleece length to be not generally affected by body regions Harmancıoğlu [45] and Lupton et al. [58] reported that the longer the fleece used in weaving, the higher the quality. It has been stated in the studies of different researchers that the characteristics of the fleece can vary according to different parts of the body, as well as the structure of the skin [37,45,53–63]. The findings we found and obtained by different researchers support each other. Champion and Robards [34] suggested that the primary and secondary follicles in the skin of the sheep create differences in terms of the number of the hair follicles and volume of the different body regions and this situation can affect the quality characteristics of the wool. Coarse fibres grow from primary follicles, while fine fibres grow from secondary follicles. The number of primary and secondary follicles, as well as secondary to primary (S/P) follicle ratio as an indicator of fibre quality, may vary between body regions and breeds. In the studies investigating the fleece properties, Kazmi et al. [64] found that the number of primary and secondary follicles and S/P follicles rates were low in the hind body regions. The differences between the body regions in our study can be attributed to the fact that our study population is composed of three different merino crossbreds and that the care supply during the period of follicle formation is highly variable [64,65].

Champion and Robards [34], Aştı et al. [66], Özfiliz et al. [67] and Tuncer and Cengiz [68] conducted studies on different genotypes, reported that primary and secondary follicles numbers and volumes in the skin can vary depending on body regions, age, and breed, and this can affect fleece characteristics. However, it is seen that the characteristics of wool obtained from every breed, age and body region are suitable for evaluation by the textile industry. Our results are in agreement with the findings of other researchers in terms of age [24,38,56,63,69] and body region [10,11,34,55,61,70,71].

Correlations between the age, live weight and fleece characteristics of sheep are given in Tables 6–8. As indicated in Table 6, there were positive and negative correlations among the observations of the Karacabey merino sheep in terms of live weight, fleece yield, and the morphological and physical characteristics of the fleece ($p < 0.01$; 0.05). An interaction for fleece properties was also detected in Karacabey Merinos ($p < 0.01$; 0.05).

The present study determined that there was a relationship between some of the morphological and physical characteristics of the fleece with age, body weight and body region among the fleece characteristics in CAM sheep ($p < 0.01$; 0.05). The relationship between age and all other characteristics except raw fleece yield were found to be statistically significant in Ramlıç sheep ($p < 0.01$; 0.05). The highest correlation coefficient was found between live weight and dirty fleece weight for the fleece properties ($r = 0.767$; $p < 0.01$). It has been reported that age has a very important effect on fleece characteristics in sheep [11,13,24,31,35,71,72]. Sumner and Bigham [53] stated that the correlations were varied between 0.3–0.5; Safari et al. [73] found correlations for fleece diameter and length in Merino sheep is in the range of 0.01–0.37; Tuncer et al. [12] found correlations between fleece length and diameter in the range r = 0.53–0.71, between elasticity r = 0.27–0.55, between strength r = 0.58–0.81, between fleece diameter and elasticity r =0.25–0.45, between strength r = -0.07–0.59; between elasticity and strength r = 0.27–0.61 in Norduz sheep. Also, Safari et al. [73], Hynd et al. [74], Purvis and Swan [75], Holman et al. [76], Malau-Aduli et al. [77] reported that there may be different levels of correlations between phenotypic characteristics of fleece in their studies on different breeds. The reports of the researchers and the results of our study are almost similar, and it can be said that the differences may have been caused by genetic and environmental factors.

5. Conclusion

In this study, which examined some factors (breed, age, and body region) that were influential on the quality of the fleece in merino crossbreed sheep, it was determined that environmental factors on the diameter of the structure were statistically effective. Accordingly, the greasy wool weight varies depending on age and breed. The finest fleece among the breeds was detected in KM, followed by Ramlıç sheep and CAM. It Cn be said that the fleece to be used in the textile industry can be obtained from lambs, yearlings, and primiparous animals in KM and Ramlıç sheep and lambs in CAMs.

The fibre lengths were not statistically affected by body regions but varied depending on age. The longest fibres were obtained from the yearling in all three breeds. There was no significant change in the length of the structure as the age progressed from the age of 2 years in the sheep included in the study. However, in all three breeds, the structure obtained from animals of all ages were in line with the criteria of the textile industry in terms of fibre length. The fleece elasticity and tenacity values among breeds showed significant variation. The fibre tenacity, which is an important parameter in terms of yarn quality, is determined as the highest in CAM and the lowest in KM. Moreover, Ramlıç sheep has the softest fibre. Our results showed that KM sheep has the most suitable fibre of length, elasticity, and tenacity in terms of the use of the textile industry.

In terms of age, the suitable fleece was obtained from lambs in KM and Ramlıç sheep, in the yearling and primiparous, and from lambs in CAM. When the breeds are evaluated in terms of body regions, it is seen that the structure obtained from the shoulder and rib areas of KM and Ramlıç sheep easily meets the criteria of the textile industry. Therefore, the fibres should be collected from the shoulder of animals to use in the high-quality textile. Although significant variations in age were identified between the breeds age and body region, no systematic or common groupings were made.

Generally, it can be said that the results obtained from this study are promising in terms of meeting Turkey's demand for high-quality wool in the textile industry with merino crossbreed. It should be remembered that Merino sheep, which are bred in our country, have high meat and wool production. It has been determined that these breeds produce fine and uniform fleece as well as other favourable fleece characteristics. It is seen that there is variation in terms of fleece yield among breeds. Considering this variation, it is necessary to carry out selection studies for the production of the fleece of the desired quality. At the same time, it is important to carry out genetic studies on the quality characteristics of wool in terms of increasing the quality in production. Finally, it will be beneficial for both the textile industry and farmers to pay attention to studies that can systematically classify the quality of the fleece based on breed and age. It is essential to develop the structure classification systems used especially in different countries within domestic breeds.

Acknowledgements
The authors would like to thank the Research Funding of Hatay Mustafa Kemal University Coordinatorship of Scientific Research Projects for the financial support of this project (Project No: 18. D. 009). We acknowledge the Republic of Turkey Ministry of Food, Agriculture, and Livestock for supplying animal materials and the Lalahan International Centre for Livestock Research and Training for providing laboratory facilities to carry out fibre analysis. This study was produced from the author's doctoral thesis.

Conflict of interest
The authors of the study sincerely declare no conflict of interest.

References

1. Anonymous 2020. IWTO Specifications for Wool Sheep Welfare. International Wool Textile Organisation (IWTO), Rue de l'Industrie, 4 Brussels, 1000, Belgium.
2. Sönmez R, Kaymakçı M, Eliçin A, Tuncel E, Wassmuth R et al. Improvement studies in Turkey sheep husbandry. Journal of Agricultural Faculty of Uludag University 2009; 23 (2): 43-65. (in Turkish with an abstract in English).
3. TUİK (Türkiye İstatistik Kurumu), Hayvansal üretim istatistikleri, 2019. Erişim tarihi 5 Mayıs.
4. Yalçın BC, Müftüoğlu S, Yurtçu B. Possibilities of improving important production characteristics of Konya Merino sheep through selection. I. performance levels for different characteristics. Journal of Ankara University Veterinary Faculty 1972; 19 (1-2): 227-255. (in Turkish with an abstract in English).
5. Akçapınar H. Alman Et Merinosu ve Karacabey Merinoslarının canlı ağırlık, beden yapısı ve yapağı verimi yönünden karşılaştırılması. Ankara Üniversitesi Veteriner Fakültesi Dergisi 1983; 30 (11): 201-205.
6. Demir H. Ramlıç ve Dağlıç koyunlarının melezlenmesi ile elde edilen çeşitli genotiplerin karşılaştırılması. İstanbul Üniversitesi Veteriner Fakültesi Dergisi 1995; 21 (1): 131-141.
7. Koyuncu M, Tuncel E, Ferik A. Anadolu Merinosu, Kıvırcık, Türkgeldi koyunlarının yapağı verim ve özellikleri üzerine bir araştırma. Uludağ Üniversitesi Ziraat Fakültesi Dergisi 1996; 12: 101-108.
8. Dellal G, Söylemezoğlu F, Etikan S, Erdoğan Z. A Research on some wool characteristics of Anatolian merino ewes. Tarım Bilimleri Dergisi 2000; 6 (2): 48-53. (in Turkish with an abstract in English).
9. Yıldız N, Denk H. Some of production traits of Akkaraman ewes raised by farmers in Van region II. fleece yield, fleece length, body measurements, birth weights of lambs and lamb survival. Fırat Üniversitesi Sağlık Bilimleri Dergisi 2006; 20 (1): 29-37. (in Turkish with an abstract in English).
10. Uzun Kara HŞ. Türkiye yerli koyun ırkları ile bazı melez koyun genotiplerinin yapağı özellikleri ve yapağının sanayide kullanılabilirliği üzerine bir araştırma. Doktora Tezi, Uludağ Üniversitesi Fen Bilimleri Enstitüsü Zootekni Anabilim Dalı, Bursa, Türkiye, 2008.
11. Peşmen G, Yardımcı M. Menemen koyununa ait yapağı özellikleri: I. Morfolojik ve fiziksel özellikler. Eurasian Journal of Veterinary Sciences 2012; 28 (2): 99-105.
12. Tuncer SS. Sireli HD, Dellal G. Comparative analysis of various fleece characteristics of Norduz and Zom sheep. Journal of Animal and Plant Science 2017; 27: 763-770.
13. Bağkesen Ö, Koçak S. Body weight after shearing, greasy fleece weight and some fleece traits of Ramlıç and Dağlıç. Kocatepe Veterinary Journal 2018; 11 (2): 148-155. doi: 10.30607/kvj.402769 (in Turkish with an abstract in English).
14. Scobie DR, Grosvenor AJ, Bray AR, Tandon SK, Meade WJ et al. A review of wool fibre variation across the body of sheep and the effects on wool processing. Small Ruminant Research 2015; 133, 43-53. doi: 10.1016/j.smallrumres.2015.10.025
15. Li W, Guo J, Li F, Niu C. Evaluation of Crossbreeding of Australian superfine merinos with Gansu Alpine fine wool sheep to improve wool characteristics. PLoS ONE 2016; (11): e0166374. doi: 10.1371/journal.pone.0166374
16. Singh H. Gahlot GC, Narula HK, Pannu U, Chopra A. Effect of genetic and non-genetic factors on wool traits in Magra sheep. Veterinary Practitioner 2018; 19 (1): 119-122.
17. Murphy TW, Stewart WC, Notter DR, Mousel MR, Lewis GS et al. Evaluation of Rambouillet, Polypay, and Romanov–White Dorper x Rambouillet ewes mated to terminal sires in an extensive rangeland production system: body weight and wool characteristics. Journal of Animal Science 2019; 97: 1569-1577. doi: 10.1093/jas/skz070

18. Atav R, Ünal PG. Soysal İS. Investigation of the quality characteristics of wool obtained from Karacabey merino sheep grown in Thrace region-Turkey. Journal of Natural Fibers 2020. doi: 10.1080/15440478.2020.1795777

19. SPSS 2012. IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA: IBM Corp.

20. Ünal N, Akçapınar H. Some important production traits of central Anatolian Merino sheep and possibilities of improving through selection of these traits I. important production traits. Lalahan Hayvancılık Araştırma Enstitüsü Dergisi 2001; 41 (1): 45-58. (in Turkish with an abstract in English).

21. Elibol M, Dağ B. Parameter estimates of factors affecting body weight at shearing and wool production traits of Akkaraman, Awassi and Awassi x Akkaraman (F_1 x AWB_1) crossbreed sheep raised in Ereğli sheep breeding station. Selçuk Tarım Bilimleri Dergisi 2004; 18 (34): 1-10. (in Turkish with an abstract in English).

22. Yılmaz O, Denk H. Fleece yield and characteristics of Norduz Sheep. Veteriner Bilimleri Dergisi 2004; 20 (3): 81-85. (in Turkish with an abstract in English).

23. Hama AA. Süleymaniye ilinde Karadi koyunun yapağı verimi. Yüksek lisans tezi, Süleymaniye Üniversitesi Ziraat Fakültesi Süleymaniye Üniversitesi Enstitüsü, 2005, Erbil, Irak.

24. Hatcher S, Atkins KD, Thornberry KJ. Age changes in wool traits of Merino sheep in Western NSW. In: Proceedings of the 16th Conference of the Association for the Advancement of Animal Breeding and Genetics, Noosa Lakes, Queensland, Australia, 2005 pp. 314-317.

25. Sezenler T, Köycü E, Özder M, Kardağ O, Erdoğan İ. The effects of body condition score and age on some reproductive performances of Karacabey Merino ewes. Tekirdağ Ziraat Fakültesi Dergisi 2007: 4 (3): 277-281. (in Turkish with an abstract in English).

26. Ceyhan A, Sezenler T, Yıldırır M, Erdoğan İ. Reproductive performance and lamb growth characteristics of Ramlıç sheep. Kafkas Universitesi Veteriner Fakultesi Dergisi 2010; 16 (2): 213-216.

27. Yılmaz O, Sezenler T, Alarslan E, Ata N, Karaca O et al. Karacabey Merinosu, Karya ve Kıvırcık kuzularda sütten kesim döneminde kabuk yağı kalınlığı ve musculus longissmus dorsi thoracis et lumborum (MLD) Derinliğinin Ultrason Ölçümleri. Kafkas Üniversitesi Veteriner Fakültesi Dergisi 2014; 20 (6): 829-834.

28. Koçak S, Çelikoğlu K, Çelik HA, Bozkurt Z, Tekerli M. Fattening performance, slaughtering and carcass traits of Pırlak, central Anatolian merino and central Anatolian Merino x Pırlak F_1 lambs. Lalahan Hayvancılık Araştırma Enstitüsü Dergisi 2016; 56 (2): 41-47. (in Turkish with an abstract in English).

29. Ambarcıoğlu P, Kaya U, Özen D, Gürcan İS. An examination of the relationships between live weight and body measurements in Karacabey Merino sheep through the path analysis approach. Kafkas Universitesi Veteriner Fakultesi Dergisi 2017; 23 (6): 857-863. doi: 10.9775/kvfd.2017.17659

30. Şahin Ö, Boztepe S, Keskin İ. Estimation of live weight, live weight gain and feed consumption values by using the means of body measurements of Anatolian merino male lambs at fattening period. Selcuk Journal of Agriculture and Food Sciences 2018; 32 (2): 142-145.

31. Sahoo A, Soren NM. Nutrition for wool production. Webmed Central Nutrition 2011; 2 (10): WMC002384. WebmedCentral.

32. Khan MJ, Abbas A, Ayaz M, Naeem M, Akhter MS et al. Factors affecting wool quality and quantity in sheep. African Journal of Biotechnology 2012; 11 (73): 13761-13766.

33. Ansari-Renani HR, Moradi S. Fiber quality of carpet-wool sheep breeds. In: Proceeding of the 2nd International Seminar on Animal Industry, Jakarta, 2012 pp. 599-605.

34. Champion SC, Robards GE. Follicle characteristics, seasonal changes in fibre cross-sectional area and ellipticity in Australasian specialty carpet wool sheep, Romneys and Merinos. Small Ruminant Research 2000; 38: 71-82. doi: 10.1016/s0921-4488(00)00141-3

35. Küçük M, Yılmaz O, Ateş CT. The evaluation of Morkaraman, Hamdani and Karakul wool for carpet type. Yüzüncü Yıl Üniversitesi Veteriner Fakültesi Dergisi 2000; 11 (2): 54-59. (in Turkish with an abstract in English).

36. Karakuş K, Tuncer SS, Arslan S. Comparison of the fleece characteristics of Karakaş and Norduz Sheep (Local ewes in Turkey). Journal of Animal and Veterinary Advances 2005; 4 (6): 563-565.

37. Ahmad S, Khan MS, Khan MFU. Factors affecting wool characteristics of Kari sheep in Pakistan. Turkish Journal of Veterinary and Animal Science 2010; 34 (6): 485-492. doi: 10.3906/vet-0705-21

38. Scobie DR, Grosvenor AJ, Bray AR, Tandon SK, Meade WJ et al. A review of wool fibre variation across the body of sheep and the effects on wool processing. Small Ruminant Research 2015; 133: 43-53. doi: 10.1016/j.smallrumres.2015.10.025

39. Lamb PR. Wool quality for spinners. Belmont, Victoria: Commonwealth Scientific and Industrial Research Organisation Textile and Fibre Technology Lamb 1997; Report No: WT97.05.26p.

40. Wood E. Textile properties of wool and other fibres. Wool Technology and Sheep Breeding 2003; 51: 272-290.

41. Lyons B. Australian Merino wool. In: Proceedings of the symposium on natural fibres, 2008, Rome, Italy, pp. 83-109.

42. Holloway HJ. Analysis of the effects of sire and age on wool quality traits in Romney ewes. Degree of Bachelor of Agricultural Science 2017. Lincoln University.

43. Atav R, Ünal PG, Soysal Mİ. Investigation of the quality characteristics of wool obtained from Karacabey Merino sheep grown in Thrace region-Turkey. Journal of Natural Fibers 2020, doi: 10.1080/15440478.2020.1795777

44. Sönmez R. Yapağı. Erzurum, Ziraat Fakültesi ders kitapları serisi No: 6, Atatürk Üniversitesi Basımevi, 1963.

45. Harmancıoğlu M. Lif Teknolojisi (Yün ve Deri Ürünü Diğer Lifler). İzmir, Ege Üniversitesi Ziraat Fakültesi Yayınları, 1974.

46. Erdem N. A research about some important wool properties of Turkish Merino raised in Karacabey State Farm. Tekstil ve Konfeksiyon 1993; 2: 81–84.

47. Erdem N. Yeni koyun tiplerinden yeni yapağı çeşitlerine doğru. Tekstil ve Teknik 1991; 7 (789): 10-14.

48. Rogers GE. 2006. Biology of the wool follicle: an excursion into a unique tissue interaction system waiting to be re-discovered. Experimental Dermatology 2006; 15: 931-949. doi: 10.1111/j.1600-0625.2006.00512.x

49. Yüceer B, Akçapınar H, Özbaşer FT. The body weight and fleece traits of Acıpayam sheep. Lalahan Hayvancılık Araştırma Enstitüsü Dergisi 2010; 50 (2): 73-80. (in Turkish with an abstract in English).

50. Zinalabidin MMZ. Karadi koyununda yapağı verimi ve bazı yapağı özellikleri. Yüksek Lisans Tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü Zootekni Anabilim Dalı, Konya, Türkiye, 2017.

51. Aziz KO, Al-Oramary RAS. A study on fleece characterization of Hamadani sheep in Erbil plain. Mesopotamia Journal of Agriculture 2005; 33 (1): 28-39.

52. Henderson AE, Hayman BI. Methods of analysis and the influence of fleece characters on unit area wool production of Romney lambs. Australian Journal of Agricultural Research 1960; 11 (5): 851-870.

53. Sumner RMW, Bigham L. Biology of fibre growth and possible genetic and non-genetic means of influencing fibre growth in sheep and goats: a review. Livestock Production Science 1993; 33: 1-29.

54. Tuncer SS. Akkaraman, Anadolu Merinosu, Ile de France x Akkaraman (G_1) ve Ile de France x Anadolu Merinosu (G_1) melezlerinde yapağı verim ve özellikleri. Yüksek Lisans Tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü, Ankara, Türkiye, 1994.

55. Boztepe S. Koyun Yetiştiriciliği. 1. Baskı, Selçuklu, Konya, Selçuk Üniversitesi Basımevi, 2015.

56. Tuncer SS, Cengiz F. Akkaraman, Anadolu Merinosu, Ile de France x Akkaraman (G_1) ve Ile de France x Anadolu Merinosu (G_1) melezlerinde yapağı verim ve özellikleri. Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi 2018; 28 (3): 353-357.

57. Arık İZ, Dellal G, Cengiz F. Anadolu Merinosu, Akkaraman, Ile de France x Anadolu Merinosu (F_1) ve Ile de France x Akkaraman (F_1) melezi koyunlarda bazı yapağı fiziksel özellikleri. Turkish Journal of Veterinary and Animal Science 2003; 27 (3): 651-656.

58. Lupton CJ, McCool A, Stobart RH. Fiber characteristics of the Huacaya Alpaca. Small Ruminant Research 2006; 64: 211-224. doi: 10.1016/j.smallrumres.2005.04.023

59. Craven AJ, Sumner RMW. Variation of fibre and follicle characteristics related to wool bulk over the body of Perendale ewes: Implications for measurement of wool bulk Proceedings of the New Zealand Society of Animal Production 2000; 60: 166-170.

60. Bray M. Regulation of wool and body growth: Nutritional and molecular approaches. PhD, The University of Adelaide Faculty of Sciences, Department of Animal Sciences, Roseworthy Campus, Australia, 2002.

61. Rufaut NW, Goldthorpe NT, Wildermoth JE, Wallace OA. Myogenic differentiation of dermal papilla cells from bovine skin. Journal of Cellular Physiology 2006; 209: 959-966. doi: 10.1002/jcp.20798

62. Craven AJ, Ashby MG, Scobie DR, Nixon AJ. Variation of wool characteristics across the body of New Zealand Wiltshire sheep. Proceedings of the New Zealand Society of Animal Production 2007; 67: 339-344.

63. Akhtar M, Javed K, Abdullah M, Mirza RH, Elzo MA. Environmental factors affecting greasy wool yield traits of Buchi sheep in Pakistan. Journal of Animal and Plant Sciences 2014; 24 (3): 685-692. doi: 10.13140/2.1.1531.4562

64. Kazmi A, Wani SA, Sofi AH, Mir MS, Khan HM et al. Effect of sex and body region on the wool follicular characteristics of Bakarwal sheep. Indian Journal of Small Ruminants 2016; 22 (1): 131-133. doi: 10.5958/0973-9718.2016.00027.1

65. Chapman RE, Ward KA. Histological and biochemical features of the wool fibre and follicle. In: Black JL, Reis PJ (editors). Physiological and Environmental Limitations to Wool Growth. University of New England Publishing Unit, Armidale, 1999. pp. 193-208.

66. Aştı RN, Kurtdere N, Sağlam M, Tanyolaç A, Eren Ü et al. The investigation on the skin strueture of the German Blaekhead x Akkaraman, Awassi and Konya Merino erossbred (F_1 and B_1) sheep. Ankara Üniversitesi Veteriner Fakültesi Dergisi 2000; 47: 145-156. (in Turkish with an abstract in English).

67. Özfiliz N, Balıkçıer M, Erdost, H, Zık B. Histological and morphometric features of the skin of native and hybrid (F_1) sheep. Turkish Journal of Veterinary and Animal Science 2002; 26: 429-438. (in Turkish with an abstract in English).

68. Tuncer SS, Uslu S, Budag C, Alarslan E, Karakuş K et al. Effect of different levels of feed consumption on the quality of fleece and number of fiber follicles in Norduz lambs. Van Veterinary Journal 2016; 27 (1): 37-42.

69. Ünal N, Akçapınar H, Atasoy F, Koçak S, Aytaç M. The body weight and fleece traits of White Karaman, Chios x White Karaman F_1, B_1, Kıvırcık x White Karaman F_1, B_1, Karayaka and Bafra sheep. Lalahan Hayvancılık Araştırma Enstitüsü Dergisi 2004; 44 (2): 15-25. (in Turkish with an abstract in English).

70. Tuncer SS, Uslu S, Taş A, Şireli HD. The densities of fiber follicles in the Karakaş, Norduz and Zom sheep and a comparative analysis. Australia Journal of Veterinary Science 2018; 50: 21-26.

71. Oğan M. Possibilities of improving important production characteristics of Karacabey merino through selection. I. Performance levels for different characteristics. Lalahan Hayvancılık Araştırma Enstitüsü Dergisi 1994; 34 (1-2): 47-58. (in Turkish with an abstract in English).

72. Ponzoni RW, Fenton ML. Phenotypic and genetic parameters from fine, medium and strong wool Australian Merino strains. SARDI and the Woolmark Company 2000.

73. Safari E, Fogarty NM, Gilmour AR, Atkins KD, Mortimer SI, et al. Genetic correlations among and between wool, growth and reproduction traits in Merino sheep. Journal of Animal Breeding and Genetic 2007; 124 (2): 65-72. doi: 10.1111/j.1439-0388.2007.00641.x

74. Hynd PI, Ponzoni RW, Grimson R, Jaensch KS, Smith D et al. Wool follicle and skin characters –Their potential to improve wool production and quality in Merino sheep. Wool Technology and Sheep Breeding 1996; 44 (3): 167-177.

75. Purvis IW, Swan AA. Breeding for wool processing performance and product quality in Merino sheep. In: Proceedings 6th World Congress Genetics Applied to Livestock Production, 1998.

76. Holman HWB, Kashani A, Malau-Aduli AEO. Wool quality traits of purebred and crossbred merino lambs orally drenched with spirulina (Arthrospira Platensisi). Italian Journal of Animal Science 2014; 13 (2): 387-391. doi: 10.4081/ijas.2014.3174

77. Malau-Aduli, AEO, Nguyen DV, Le HV, Nguyen QV, Otto JR. Correlations between growth and wool quality traits of genetically divergent Australian lambs in response to canola or flaxseed oil supplementation. PLoS ONE 2019; 14 (1): e0208229. doi: 10.1371/journal.pone.0208229