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Effects of Age, Body Region and Mineral Contents on the Fleece Characteristics of Central Anatolian Merino Sheep

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ABSTRACT

The fibre characteristics of fleece determine its fate through the textile industry. Parameters such as diameter, length, elasticity and strength define the functional quality of fleece. Therefore, the aim of the present study was to investigate effects of different environmental factors as well as wool mineral contents on fleece fibre quality traits in Central Anatolian Merino sheep (CAM). Additionally, the mineral contents of CAM fleece were investigated. For this purpose, 300 samples were equally collected from 3 different body regions (shoulder, rib and rump) of 100 animals from five different age groups. Samples were analysed for fibre quality (diameter, length, elasticity and strength) traits and mineral contents (calcium, iron, potassium, magnesium, copper, manganese and zinc). A wide range of statistical relationships were found among the focused traits and those factors. The findings of this study highlight the importance of minerals as well as environmental factors on fleece qualityparameters.

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Central Anatolian Merino, sheep, wool quality, minerals, environmental factors.

1. INTRODUCTION

Historical use of natural fibres in textile, with the purpose of clothing and protection from severe natural conditions, was recently found to be dating approximately 170.000 years ago and the fibre from the various breeds of sheep (wool) is by far the most commonly-used animal fibre [1, 2]. However, recent sustainability concerns rendered yield and quality to be the two major components of the fibre production for textile purposes. Furthermore, organic fibre production, as a recently focused concept, promotes the use of natural fibres in clothing sector [3]. When the countries producing fleece that is suitable for textile industry are examined, Australia appears to be the major fleece producing country with 24 % of the global fleece production, while China, New Zealand and South Africa follows with 15 %, 10 % and 2.6 %, respectively [4].

As it is widely known, most of the global wool production is sourced from Merino sheep and its crossbreds [5]. Additionally, Merino is considered among the primary sheep breeds that is meeting the fibre quality demands of the textile industry [6]. Merino, with a population size of approximately 3 million of animals and 9453 tonnes of wool produced, is among the major sheep breeds of Turkey that extensively contributes overall meat and fleece production [7]. Crossbreeding Merino with an indigenous sheep breed is currently a popular approach to utilize its productivity as well as fibre quality while increasing the adaptive capacity of the crossbred [5, 8, 9]. It is also expected that the fleece to demonstrate uniformity among different body parts. However, several studies focused on various species previously showed that body parts have significant differences regarding fibre characteristics [10-12].

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The fibre characteristics of fleece determine its fate through textile industry. Parameters such as diameter, length, elasticity and strength define the functional quality of fleece. Particularly, fibre diameter and length are important factors affecting industrial processing of fleece for textile usage [13]. On the other hand, elasticity and strength are the other factors which alter the efficiency of production as well as the lifespan of the final product [14, 15].

There are several factors contributing fleece yield, quality and uniformity in sheep such as genetic, age, breed, body parts and content of feed [10, 16 ,17]. For example, the lack of zinc, copper and amount of mineral matter negatively affects the length and fineness of the fleece. [18-20].

Therefore, the aim of the present study was to investigate the effects of different environmental factors as well as wool mineral contents on fleece fibre quality traits in Central Anatolian Merino sheep. Additionally, the descriptive characteristics of mineral contents of Central Anatolian Merino fleece were determined.

2. MATERIAL AND METHOD

2.1 Material

Animal procedures were approved by the International Centre for Livestock Research and Training Research Animal Care and Use Committee (29.11.2016/2787-131). The study was carried out on 100 Central Anatolian Merino sheep. It is a crossbred of German Mutton Merino and Akkaraman (White Karaman) sheep, owned by the farmer under the National Community-Based Small Ruminant Breeding Programme in Ankara, Turkey. In total, 300 samples were equally collected from 3 different body regions (shoulder, rib and rump) of 100 animals which belong to five different age groups. 25-50 gr fleece samples were collected from each body region (shoulder, rib and rump) of animals by shearing machine. As routine management practice, the animals used in the study and all other animals in herds are sheared once a year in June. Further details on the study population were given by [21].

2.2 Method

The fleece samples were analysed for fibre quality traits and mineral contents in the laboratories of the International Center for Livestock Research and Training. The fibre diameter and length measurements were implemented on OFDA 100 [22]. The analysis of fibre length; the fibres were first aligned and straightened from the one end and placed into the OFDA 2000 device and automatically measured by the optical measuring tool of the instrument in millimetres (mm) [23, 24]. The fibre elasticity and strength were measured on the FAFEGRAPH METM (Textechno, Moenchengladbach, Germany) instrument. Finally, calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), copper (Cu), manganese (Mn) and zinc (Zn) contents were determined using atomic absorption spectroscopy. Additionally, the information on body regions (shoulder, rib and rump) and age were recorded as categorical variables. Animals were categorized by age in five groups as 1 (<6-month), 2 (12-18-month), 3 (18-30-month), 4 (30-42-month) and 5 (>42-month).

Statistical Analyses

The descriptive statistics were obtained and presented in Table1. To estimate the effect sizes of different environmental factors, multiple univariate linear regression analyses were performed for each trait. Subsequently, Duncan's Test were implemented to those significant categorical variables to obtain multiple comparisons among groups [25]. Lastly, Pearson's correlations were obtained between the traits. All statistical analyses were performed using the base packages of R statistical environment [26].

The outliers of the variables (i.e. values exceeding mean ± 3 x standard deviation) were checked. Primarily, the effects of different environmental factors and covariates were tested to build final linear model with all significant effects for each trait. Subsequently, the linear regression models were fitted with relevant significant factors and covariates to estimate the effect size of body region, age groups, Ca, Fe, K, Mg, Cu, Mn and Zn on diameter, length, elasticity and strength. Normality of the traits were tested with Shapiro-Wilk test. Furthermore, homogeneity of variance was visually inspected by plotting residual vs fitted values of the traits. The linear regression model descriptions for responses are given below:

Model; $y_{ijk} = \mu + a_i + c_j + b_{ijk} X + e_{ijk}$

Where y_{ijk} are the observations of the dependent variables (i.e., fibre diameter, length, elasticity and strength); μ is the intercept; a_i is the effect of age groups (5 levels); c_j is the effect of body regions (3 levels); b_{ijk} is the regression coefficient of independent variables (mineral contents); X is the incidence matrix of fixed effects; and e_{ijk} is the residual error of observations in the models.

3. RESULTS AND DISCUSSION

In this study, the characteristics of fleece minerals and the effects of age, body region and fleece mineral contents were investigated on the fibre quality traits of Central Anatolian Merino sheep. With this purpose, regression based statistical analyses were conducted. The responses were checked for the outliers which were removed from further analyses. Descriptive statistics for fibre diameter, length, elasticity, strength and the mineral contents are presented in Table 1. The responses were normally distributed and showed homogenous variance. During the models building stage, all interactions between independent variables were checked and no interaction was found. After the preliminary significance testing, those significant effects suggested in Table 2 were used to build final models for each trait. Accordingly, full models explained 0.21, 0.60, 0.11 and 0.16 of the total variances presents in the fibre diameter, length, elasticity and strength respectively.

The difference between each group for each dependent variable was determined by regression analysis and this difference was given as effect size in Table 2. The effect sizes obtained in the regression analysis define the difference between groups when all other fix factors in the model are zero. Studies regarding estimation of the effect sizes for age, body region and mineral contents on fibre quality parameters were extremely scarce in the literature, which nominates our study among the very first studies regarding the topics. Therefore, the effect sizes found in our study were evaluated against various correlations and least square estimates of comparable studies where appropriate.

3.1 Fleece Mineral Contents

The relevant descriptive statistics were presented in Table 1. The mean Ca content of fleece in the study was found to be 550.40 mg/kg. It Fe content of fibre varies from 13.60 mg/kg to 52.8 mg/kg [30, 31]. The mean Fe content of fleece in this study was found to be 29.34 mg / kg. This falls within the range provided by previous studies. On the other hand, K contents from previous studies were found between 204 and 2499.2 mg/kg [19, 32, 33]. Similarly, the mean K content of fleece in our study drop within this range with 392.16 mg / kg on average. The reports show that Mg content of fleece in sheep has a wide range of 47.8-590.8 mg / kg [19, 32, 33]. In our study, the mean of Mg content was 221.16 mg/kg. The content of Cu and Zn were 3.79 mg/kg and 82.90 mg/kg, respectively. Various studies reported Cu and Zn contents ranging between 1.70 - 25 mg/kg and 18.3 - 336.9 mg/kg respectively, which are consistent with this study [30, 34–36]. Lastly, the content of Mn was found to be 27.61 mg/kg. Previously, studies reported Mn contents higher than [27] and slightly lower than [19] our findings.

The reference range of the mentioned minerals were observed to be extremely varying among different studies. Possible reasons for these discrepancies were suggested to be the condition of pasture (i.e., soil, plant) and the feed type which are known as significantly effective on the mineral content of fleece [16]. Accordingly, the mineral content of fleece is observed in a wide spectrum as seen in our study and previous studies.

3.2 Fibre Diameter

In the study, the mean fibre diameter was found as 24.18 µm, which is well suited for textile industry since it is slightly below than the commonly accepted threshold of 24.6 µm [3]. In Karacabey Merino sheep, Atav et al. [9] reported that the mean of wool diameter as

28.67 µm which is higher than our result. However, the study conducted on Saxon Merino sheep and Anatolian Merino sheep (i.e., Central Anatolian Merino), the fibre diameters were found respectively, as 18.8 µm and 20.08 µm which is significantly lower than our study [37, 38].

The linear regression model was fitted for fibre diameter and the effect of age, body region, Zn content were found to be significant (p- value <0.05). The effect size of age groups was presented on Table 2. According to the results, the intercept for the model was estimated as 23.26 ± 0.33 µm and the effect sizes of 2., 3., 4. and 5. age groups were 0.96 ± 0.41, 0.47 ± 0.37, 0.94 ± 0.38 and 1.31 ± 0.40 µm respectively. The differences between 1-4 and 1-5 groups were found statistically significant (p-value<0.05). The detailed information of multiple comparisons was presented in Table 3. The study conducted by Atav et al. [9] reported that the fibre diameter of younger (0-2 ages) animals is coarser than the elders (above 2 ages). The results of this study correspond to the results of our study. Generally, studies suggest that age significantly affects fibre diameter and increasing age leads to the increased fibre diameter [39].

The effect size of the body regions was estimated and according to the results, the diameter of samples taken from rump was 1.97 ± 0.30

µm higher than the samples taken from shoulder and rib (See Table 2). As shown in the Table 3, while the differences between shoulder- rump and rib-rump were significant (p-value<0.05), the difference between shoulder and rib was not significant. The study conducted on Karacabey Merino sheep found shoulder, rib and rump fibre diameters of 28.46, 28.19 and 29.33 µm respectively [10]. Similar with the current study, the coarser fibre diameter was found for rump and the thinner were found for shoulder and rib. Additionally, a previous study implemented on Anatolian Merino sheep found that the fibre diameter of rump to be coarser the other regions [40].

Table 1. Descriptive statistics of the variables.

Variables	N	Mean	sd	Minimum	Maximum
Diameter (µm)	295	24.18	2.29	19.21	31.01
Length (cm)	299	6.04	1.67	2.50	10
Elasticity (%)	292	24.52	6.44	6.28	42.12
Strength (cN)	286	16.48	4.77	8.17	31.77
Ca (mg/kg)	300	550.40	204.22	122.16	1067
Fe (mg/kg)	196	29.34	25.95	3.40	271.60
K (mg/kg)	299	392.15	4.29	6.93	2945
Mg (mg/kg)	300	221.16	91.27	70.32	476.80
Cu (mg/kg)	288	3.79	3.03	0.60	25.70
Mn (mg/kg)	299	27.61	17.43	0.38	52.93
Zn (mg/kg)	294	82.90	68.80	9.80	383.60

Notes: N=number of observations; SD=standard deviation.

Of the minerals, only Zn was found to be effective on the diameter (p-value<0.05). Results suggests that an increase of one mg Zn in fleece was estimated to decrease 0.005 µm of fibre diameter. The thinner fibre is more demanded for the textile sector and a higher quality woven product is obtained with thinner fleece. In this context, the increase in the Zn content in the fleece reduces the thinness of the fleece and provides a positive effect on the fleece quality. Conversely, the study conducted on Merino sheep the correlation between amount of zinc in fleece and the fibre diameter was 0.68. Furthermore, Zn supplementation to feed was also found to be effective on fibre diameter in the same study. The finding of the study showed that the sheep with additional Zn had higher than control groups [41].

The correlations between the fibre diameter and other quality parameters are presented in Table 4. The correlation between the fibre diameter-length and the fibre diameter-strength were found to be significant (p-value<0.05). Moreover, the correlation values were 0.09 and 0.41, respectively. The correlation between fibre diameter and elasticity was not statistically significant. In a previous study, the correlation between the fibre diameter-length, diameter-elasticity and diameter-strength were found to be 0.54, -0.55 and -0.50, respectively in Merino sheep [40]. However, it is important note that the sample size of that study was significantly lower than our study.

3.3 Fibre Length

Descriptive statistics for the fibre length are presented in Table 1. The findings showed that the effects of age, body region, Fe, Mg and Zn on the fibre length were significant (p-value <0.05). The mean of the regression model fitted for length was calculated as 4.18 ± 0.30 cm. Further, the effect sizes of the 2., 3., 4., and 5. age groups were 3.92 ± 0.25, 2.41 ± 0.24, 2.97 ± 0.24 and 2.60 ± 0.24 cm, respectively. The multiple comparisons among the groups were presented in Table 4. The difference between group 1 and the other groups were found to be significant (p-value <0.05). Similarly, the difference between group 2 and the other age groups are significant (p-value <0.05). However, the difference between the age group 3, 4 and 5 were observed to be statistically insignificant. The group 1 had shorter length and group 2 had longer fibre length. This is probably due to the fact that while shearing is done every 12 months in adult animals (group 3, 4 and 5), this period is limited to a maximum of 6 months in group 1 (lambs) and prolonged to 18 months in group 2 (yearling). In the study of Atav et al. [9], the fiber lengths were longer than the current study, but the differences between the age groups were significant as similar to our study. Likewise, they found that the younger animals had longer fiber than the elders. The possible reason of the different fiber length between the study of Atav and our study may be different genotype and environment.

The effect sizes of the body regions on length were found as 0.23 ± 0.17 and 0.49 ± 0.19 cm for rib and rump, respectively, while the intercept was 4.18 ± 0.29 cm. On the other hand, the difference between shoulder and rump was significant (p-value<0.05), whereas, the difference between shoulder-rib and rib-rump was not significant. The length of fibres was found to be 9.10, 8.92 and 8.67 cm for shoulder, rib and rump, respectively. Similar with our study, the differences between shoulder and rump was found to be significant whereas, the differences of shoulder-rib and rib-rump were not found to be significant in a recent study [10]. In another study implemented on 18 months-old female sheep, the fibre length were 4.77, 4.83 and 4.72 cm for shoulder, rib and rump, respectively and the differences among groups were not significant [40].

Table 2. The summary of the sample size, effect sizes and relevant p-values for the analysed traits

Fixed Effects	Diameter (µm)			Length (cm)			Elasticity (%)			Strength (cN)		
	N	Effect size ± SE	P	N	Effect size ± SE	P	N	Effect size ± SE	P	N	Effect size ± SE	P
Age (year)	299		**	299		***	292		***	292		NS
1 (0-6 month)	60	---		60	---		58	---		58	---	
2 (12-18 month)	60	0.96±0.41		60	3.92±0.25		59	2.28±1.15		59	NG	
3 (18-30 month)	60	0.47±0.37		60	2.41±0.24		59	4.80±1.12		59	NG	
4 (30-42 month)	59	0.94±0.38		59	2.97±0.24		57	3.20±1.16		55	NG	
5 (>42 month)	60	1.31±0.40		60	2.60±0.24		59	4.55±1.17		59	NG	
Body regions												
Shoulder	100	---	***		---	***		--	NS		---	***
Rib	100	0.005±0.29			0.23±0.17			2.03±0.89			0.65±0.65	
Rump	100	1.97±0.30			0.49±0.19			-1.04±0.90			3.39±0.70	
Minerals												
Ca (mg/kg)	300	NG	NS	300	NG	NS	300	NG	NS	300	NG	NS
Fe (mg/kg)	196	NG	NS	196	0.013±0.004	**	196	NG	NS	196	0.04±0.01	**
K (mg/kg)	299	NG	NS	299	NG	NS	299	NG	NS	299	NG	NS
Mg (mg/kg)	300	NG	NS	300	-0.003±0.001	*	300	NG	NS	300	-0.01±0.004	***
Cu (mg/kg)	288	NG	NS	288	NG	NS	288	0.29±0.12	*	288	NG	NS
Mn (mg/kg)	299	NG	NS	299	NG	NS	299	NG	NS	299	NG	NS
Zn (mg/kg)	294	-0.005±0.001	**	294	-0.003±0.001	**	294	NG	NS	294	NG	NS
Intercept		23.26±0.33	***		4.18±0.29	***		20.07±1.06	***		17.27±0.96	***
Adj. R-squared		0.18	***		0.59	***		0.11	***		0.16	***

Notes: SE = standard error; N=number of observations; ***p <0.001; **= p < 0.01; *= p < 0.05 NS= not significant, NG=not given.

Table 3. Multiple comparison of age and body region groups (LSM ± SE)

Groups	Diameter (µm)	Age (months)	Length (cm)	Strength (cN)
		Elasticity (%)		
1 (0-6 month)	23.60 ± 0.29^{b}	3.73 ± 0.09^{c}	21.47 ± 0.86^{b}	16.04 ± 0.60
2 (12-18 months)	24.27 ± 0.27^{ab}	7.25 ± 0.16^{a}	23.97 ± 0.74^{a}	14.59 ± 0.49
3 (18-30 months)	23.98 ± 0.27^{ab}	6.04 ± 0.13^{b}	26.30 ± 0.91^{a}	15.73 ± 0.53
4 (30-42 months)	24.41 ± 0.32^{ab}	6.50 ± 0.18^{b}	24.66 ± 0.81^{a}	16.51 ± 0.59
5 (>42 months)	24.61 ± 0.32^{a}	6.09 ± 0.14^{b}	26.04 ± 0.74^{a}	15.90 ± 0.65
		Body Regions		
Shoulder Rib	23.56 ± 0.22^{a}	5.69 ± 0.16^{b}	24.17 ± 0.65^{b}	14.34 ± 0.38^{b}
Rump	23.51 ± 0.22^{b}	5.93 ± 0.16^{ab}	26.33 ± 0.68^{a}	15.21 ± 0.38^{b}
	25.81 ± 0.24^{b}	6.16 ± 0.17^{b}	22.95 ± 0.58^{b}	17.50 ± 0.43^{a}

Notes: SE = standard error.

On the other hand, the regression coefficients of Fe, Mg and Zn contents on the fibre length were found as 0.013 ± 0.004, -0.037 ± 0.001 and -0.003 ± 0.001 cm, respectively. In other words, one-unit increase in Fe content in fleece provides 0.013 cm increase in fibre length, while one-unit increase in Mg and Zn provides a decrease of 0.037 and 0.003 cm, respectively. In brief, the effect of Fe on the fibre length was favourable, however, the effect of Mg and Zn were negative. The correlation between fleece Zn content and the fibre length was to be 0.60 in Merino sheep [41]. The correlation between fibre length-diameter and the fibre length-elasticity was found to be significant (p-value<0.05) and was 0.12 and 0.22, respectively. The correlation between fibre length and strength was not found to be significant. On the other hand, they were found as 0.54, -0.11 and -0.30 for length-diameter, length-elasticity and length-strength, respectively in the study of [41]. Unfortunately, no study has been encountered for the effect of Fe and Mg on fibre quality.

3.4 Fibre Elasticity

Descriptive statistics of the fibre elasticity is presented in Table 1. In the fitted linear model, age, body regions and Cu were found to be significant (p-value<0.05). According to the results illustrated in Table 2, the intercept of the model for elasticity was 20.07 ± 1.06%. The effect sizes of age groups were found to be 2.28 ± 1.15, 4.80 ± 1.12, 3.20 ± 1.16 and 4.55 ± 1.17% for 2., 3., 4., and 5. age groups respectively. The comparative results of the difference between groups are shown in Table 3. According to these results, the difference between the group 1 and the others were found to be significant (p-value <0.05). However, no statistically significant difference was found among the other groups. The mean of fibre elasticity according to age group were found to be 19.42, 20.78 and 21.11% for 0-2, 2- 4 and 4-6 years, respectively in the Karacabey Merino sheep and the differences among the groups were not to be significant [10]. Another study conducted on Karakul sheep, the fibre elasticity was found to be 36.67, 37.68 and 37.62% for male lambs, yearling and ewes, respectively [42]. These finding were significantly higher than our study.

On the other hand, the effects of different body parts were 2.03 ± 0.89 and -1.04 ± 0.90% for rib and rump. Surprisingly, there was no difference between shoulder and rump in body regions, while the difference between shoulder-rib and rib-rump was significant (p-values <0.05). [10] reported that the fibre elasticity for shoulder, rib and rump were 20.30, 18.78 and 22.22%, respectively. They found that shoulder-rib and shoulder-rump was not significant, while rib-rump was significant. Besides, [40] showed that shoulder, rib and rump were 28.72, 26.90 and 26.43%, respectively. In the study, only the significances between shoulder and other region were significant.

Among the minerals used in the study, only Cu was found to be statistically effective (p<0.005) and was added to the fitted model as covariate variable. The regression coefficient of Cu content of fleece was found as 0.29 ± 0.12. The amount of one-unit increase of the Cu element in the fleece results in 0.29 % of increases on the elasticity of the fleece. In other words, the increase in Cu level in the fleece provides a positive effect on the elasticity characteristic. The correlation between elasticity and other quality features are seen in Table 4. Previous research has illustrated the significant effect of Cu on the hair growth in sheep [18]. As expected, a negative relationship was found between fibre diameter and elasticity (-0.08), but this relationship was not statistically significant. On the other hand, a positive direction (0.23, 0.22), respectively and a statistically significant relationship was found between fibre elasticity-length and fibre elasticity-strength (p-value <0.05). Moreover, in a previous study the correlation between elasticity-diameter, elasticity-length and elasticity-strength were reported as -0.11, -0.55 and 0.44, respectively [42].

3.5 Fibre Strength

The body region, Fe and Mg were found to be effective on the strength where no significant effect was detected for age. The mean of the model is 17.27 ± 0.96 and the effect sizes of the body regions are 0.65 ± 0.65 and 3.39 ± 0.70, respectively (Table 2). In the multiple comparison of the groups, there was no significant difference between shoulder and rib, but the difference between shoulder-rump and rib-rump were significant (p-value <0.05).

Table 4. Below the diagonal shows the correlations of the traits and above the diagonal shows p-values

Correlations/ Traits	Diameter (µm)	Length (cm)	Elasticity (%)	Strength (cN)
Diameter (µm)	---	**	NS	***
Length (cm)	0.09		***	
Elasticity (%)	-0.08	0.23		***
Strength (cN)	0.41	-0.001	0.22	

NS, not significant; ***=p<0.001; **= p < 0.01; *= p < 0.05

The regression coefficients of Fe and Mg in fleece were found to be 0.04 ± 0.01 and -0.01 ± 0.004, respectively, which means that an increase of one-unit in the amount of Fe in the fleece resulted in 0.05 cN increase in fibre strength. However, the same is not true for Mg, one-unit increase in the amount of Mg resulted in -0.01 cN a decrease in fibre strength. The correlations for fibre strength-diameter, strength-length and strength-elasticity were found to be 0.41, -0.001 and 0.22, respectively. While the correlation between fibre strength- diameter and fibre strength-elasticity were found significant (p-values <0.05), the relationship between strength and length was found insignificant. The study of [40], the correlation was found to be -0.50, -0.30 and 0.44 for strength-diameter, strength-length and strength- elasticity respectively.

4. CONCLUSION

In this study, the relationship between environmental factors such as age, body region and fleece mineral contents and the fleece characteristics were investigated in Central Anatolian Merino sheep. Furthermore, amount of various macro- and microelements in fleece were characterized. A wide range of statistical relationships were found among the focused traits and those factors. Finding of this study highlights the importance of minerals as well as environmental factors on fleece quality parameters. Therefore, the results of our study have a wide range of implications regarding various disciplines such as herd management and textile industry.

The findings of the study suggest that mineral levels have a promising potential on the improvement of the fleece quality because of the contribution to the variation in fleece quality parameters. Consequently, this improvement can be utilized for increasing the efficiency of fleece during machinery process. Further studies are suggested regarding the relationship between nutrition and the mineral contents of fleece which have great opportunity for the manipulation of fleece characteristics as indicated by our findings. On the other hand, the study enlightening the variation between age groups and body region regarding fleece quality. For instance, relationship between age and the quality traits can be used to optimize the shearing period for maximum utilization in textile industry. Furthermore, it is widely known that uniformity of fleece is critically important for efficient textile production. Our findings showed that uniformity is broken among different body regions. Hence, it should be taken into account during the raw material collection for manufacturers.

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