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Wool Fiber Quality of Naeini Sheep

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Abstract: The objective of this study was to evaluate fiber quality characteristics of Naeini sheep. An experiment was carried out on six flocks from different regions of Isfahan province. Two hundred and twenty seven Naeini sheep (191 ewes and 36 rams) were sampled from a 100 cm^2 surface on the mid-side. Fleeces shorn in 1999 within two sampling seasons (June and December) were sent to the laboratory of Animal Sciences at Isfahan University of Technology in order to study some wool quality traits including: fiber diameter mean, variability in fiber diameter, percent of true, modulated and heterotype fibers, accumulation of scales in 100 μm fiber lengths and diameter mean of modulated and heterotype fibers on Naeini sheep. Fiber diameter mean, within sample variability of fiber diameter and diameter mean of heterotype and modulated fibers were estimated 28.51, 11.19, 46.67 and 65.78 μm, respectively. The percentages of true, modulated and heterotype fibers were 89.53, 5.93 and 4.38, respectively and the average number of scales was 6.2 per 100 μm length of fiber. Herd and season had significant effects on all of the studied measures. Herd effects may be due to genetic, environment and pasture (nutritional) differences between herds. Also, the results of this study showed that there would be finer wool type at June than December shearing times for Naeini sheep. Age had a significant effect on % of heterotype fibers only and sex effect was only significant on the scales accumulation. On average, Naeini rams had finer fibers than ewes, which indicate higher selection intensities on rams. The results of this study revealed that Naeini sheep has great qualifications for carpet industry. However, further breeding programs are needed to meet textile industries qualifications.

Key words: Naeini sheep, fiber diameter, heterotype fibers, modulated fibers

INTRODUCTION

Wool production has a great impact on sheep men returns, development of carpet and handicrafts, textile industries and in general on the national economics.

Iranian carpet and wool-made handicrafts are well-known in all over the world. However, Iran has a great importation of different kinds of sheep wool from countries such as Australia, New Zealand and South Africa, every year (Salehi and Taherpoor, 1988). Growing demand for sheep wool and inconsideration of genetic improvement programs for wool quality and production for native breeds, have led to the increase in demands for wool importation to Iran. Designing breeding plans on native breeds, wool yield of Iranian breeds can be a proper replacement for imported wool and there would be a less need for wool importation.

Wool income accounts for 10 to 40% of the total gross returns from sheep husbandry. Sheep men are remained that wool production represents as a free source of income and its negligence is considered as poor business management (Botkin *et al*., 1988).

Based on the staple length, fiber diameter, variability in different kinds of fibers (true, heterotype and modulated) and fiber diameter, wool has different kinds of usage in textile and carpet industries. In carpet industries, a higher variability in fiber diameter and length within fleeces are permissible rather than textile industries (Coop, 1986).

Fiber diameter in Iranian native breeds is ranged between 27 to 42 μm; the lowest fiber diameter refers to Baloochi and Zandi breeds and the highest is related to Lori-Bakhtiari and Afshari breeds. Staple length in Iranian native breeds is ranged from 7 to 19 cm; the lowest refers to Mehraban and Sangsari breeds and the highest staple length is related to Lori-Bakhtiari and Kalkoohi breeds (Taherpoor, 1988; Taherpoor and Salehi, 1987). Most of Iranian researchers have suggested that high variability in fiber diameter and length for Iranian breeds have made their wool type suitable for carpet. Also, the percentage

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of heterotype and modulated fibers is high in major Iranian native breeds (Hasani, 1992; Salehi and Taherpoor, 1988; Siah-Kamari, 1998).

The main value-determining factor of wool is the grade of wool; which is the most important characteristic because it governs the minimum thickness of yarns that can be spun in textile factories. The minimum number of fibers in a vertical plane of a yarn to support enough strength against stress and tractions during spinning process is around 40 fibers. Grade refers to the average of fiber diameter used to express fineness quality as a comprehensive term to include all of the qualitative measures of wool (Botkin *et al*., 1988).

Fiber diameter variability within fleeces is mainly influenced by the animal's genotype and considerably affected by environmental factors such as the nutrition. Nutrition is the most important factor affecting wool traits directly or indirectly. The environmental factors can also cause variation in fiber diameter along fibers. The sources of variation in fiber diameter are (Stobart, 1986): Between fleece variations, Variation between body regions within fleeces, Variation between fibers within staples (fiber-to-fiber variation within staples has been shown as the greatest source of variation) and Variation between points along fibers.

To the manufacturer, uniformity of both fiber diameter and staple length are very important. Uniform clips require less sorting and blending to meet specifications for diameter and fiber length at various stages of processing (Botkin *et al*., 1988). Length uniformity in a clip can be increased by breeding and shearing proficiency. Also, the negative effect of end-to-end diameter variation along fibers can be minimized by controlling nutrition and management practices such as shearing time (Botkin *et al*., 1988).

Bunge *et al*. (1996) studied the correlations between objective and subjective estimates of wool traits to provide information on how laboratory values for fleece samples compare with commercial visual evaluations on the whole fleece. They found correlations between measured and estimated staple length (0.42) and between measured fiber diameter and fleece grade (-0.29) and concluded that due to lack of large correlations between measured and estimated values, visual assessments are not accurate and objective measures are more preferable to use.

The maximum wool yield of each animal and furthermore the possible variability in each qualitative wool trait is under the control of animal's genes. Heritability estimates are moderate to high for wool traits. Heritabilities of fleece weight, fleece grade and staple length were reported 0.54, 0.41 and 0.65, respectively (Hanford *et al*., 2003).

Iman *et al*. (1992) reported that phenotypic correlations are positive (0.3) between fiber diameter of mid-side wool samples and clean fleece weight, low and positive (0.08) between diameter variation and clean fleece weight and negative (-0.15) between diameter mean and variation. In general, wool quality and quantity traits are correlated unfavorably.

Several studies have shown different and contrasting results about the animal's sex and age effects on the quantitative and qualitative characteristics of wool fibers. Some researchers reported non-significant effects of age and sex on the wool fiber diameter and strength (Drummond *et al*., 1982; Ercanbrack and Knight, 1985; Robert and Parlier, 1986); while, some others showed significant effects of sex (Hasani, 1992; Siah-Kamari, 1998). Also, some studies showed that age effect significantly affected fiber diameter and the percentage of true fibers (Bunge *et al*., 1996; Hasani, 1992). Iman *et al*. (1992) reported that the effect of age is non-significant on diameter mean and variation, while it is significant on clean fleece weight. There is a definite seasonal rhythm in wool growth rate. Sheep tend to grow coarser, longer fibers and therefore more wool in summer than winter (Botkin *et al*., 1988). Considering seasonal changes, there is no single cause of seasonal variations in wool but several factors are effective, including: photoperiod, physiological state, adaptability of breed, quantity and quality of feeds (which seems to be more important in grazing systems) and temperature which has a major effect on circulation degree of blood and therefore nutrients to the skin (Botkin *et al*., 1988).

The aim of this study was to evaluate the qualitative characteristics of wool fibers for Naeini sheep and to study the effects of some environmental factors including: herd, age, sex and wool sampling season on fiber characteristics of Naeini sheep.

MATERIALS AND METHODS

Naeini sheep: Naeini sheep is one of the most important Iranian wool breeds. From the phenotypic point of view (Fig. 1), Naeini sheep is a white-colored, fat-tailed breed which has black orbits around eye-socket, nozzle, foreleg and hoof areas. Most ewes are hornless, while rams are horned. This breed has a small body size with a small fat relative to the other Iranian breeds. Most ewes lamb single and the frequency of 2 or 3 litter sizes is very low.

Naeini sheep is one of the well-known Iranian breeds for the wool quality, which is adapted to harsh environments and poor pastures. Mature weight means are 45 and 60 kg for ewes and rams, respectively. Due to its small to medium body size, fleece weight of Naeini sheep (about 1 to 1.2 kg) is not so high (Edriss, 2003).

Fig. 1: Naeini ewe (up) and ram (down)

Colorful images can be requested from the corresponding author.

Due to the small body size of this breed, herd men usually cross Naeini sheep with other heavier breeds to increase returns of progeny's meat production. Thus, except purebred flocks of nucleus breeding schemes, the majority of commercial flocks are crossbred.

Sampling and analysis: The experiment was conducted on sheep herds of Naeini breed, which were under the supervision of nucleus ram scheme of Animal Husbandry center of Agriculture organization in Isfahan province in Iran. In order to evaluate wool fiber quality traits of Naeini sheep, six herds were chosen from six different regions of Isfahan province (Isfahan city, Naein, Ardestan, Najaf Abad, Moorchekhort and Varzaneh). The wool sampling process was done in 1999 during two shearing seasons (June and December). Wool samples were taken from a 10×10 cm surface on the mid-side of each animal. Samples were collected in specific isolated envelops which were marked by a label of specific animal registration ID and then wool samples were transferred to the laboratory of Animal Sciences at Isfahan University of Technology for further measurements.

The collected data comprised records on 227 Naeini sheep; including 36 rams and 191 ewes, in 7 age classes (year). In order to facilitate the measuring procedures, samples were washed by a non-ionic detergent named Flousan in special laces at 40°C for 20 min in Ben Mary conditions to eliminate external wastes, dust and fat. Then wool samples dried at laboratory conditions and samples were ready for quantitative measuring.

A combined subjective-objective method was used to estimate the percentage of true, modulated and heterotype fibers in fleeces. In such a way, first fibers were classified by naked eye (subjectively) as far as it was possible and the remainings which were difficult to be classified by this way were categorized by an optical microscope (objectively) (ASTM, 1997). The percentage of different fiber types in each sample were estimated based on 600 measurements. In order to measure the fiber diameter, fleece samples were placed into a microtome and then vertical planes in the length of 120 μm were constructed on them. Afterwards, fibers were fixed on planes using glycerin and the fiber diameter mean and it's variability within each sample were estimated by measuring the diameter of 200 randomly chosen fibers from each sample using scaled optical lenses and Image Tool software (Don *et al*., 1995). Scales accumulation was estimated by counting the number of scales in 100 μm length of fiber for 10 randomly chosen fibers from each plane (ASTM, 1997; Don *et al*., 1995).

Statistical analyses of wool quality traits were done using Proc GLM of SAS software (SAS Inst., 1997) and mean comparisons were based on Duncan test. Also, Proc CORR of SAS software (SAS Inst., 1997) was used to estimate the correlations between the studied traits. The following model was used to estimate the effect of some environmental factors on the wool quality.

$$Y_{ijklm} = \mu + Herd_i + Age_j + Sex_k + Season_l + e_{ijklm}$$

where; Y_{ijklm} is the record observation, μ is the overall population mean, $Herd_i$, Age_j, Sex_k and $Season_l$ are the related fixed effects; and e_{ijklm} is the random residual effect.

RESULTS AND DISCUSSION

Means and variations: The fiber diameter mean was estimated 28.51 μm with 15.15% coefficient of variation (Table 1). On average, there were 6.19 scales per 100 μm length of fiber. Also, the variation mean in fiber diameter within fleece was 11.19% (Table 1). These values show that Naeini sheep is one of the most important Iranian wool breeds. Considering wool quality, the only Iranian rivals of Naeini sheep are Baloochi, Kermani and Zandi breeds. Also, the results of this study revealed that between fleeces variation in fiber diameter is higher than within fleece variation.

Table 1: Descriptive parameters for the measured wool traits

Trait	N*	Mean	SS	SD	CV	Min	Max
Fiber diameter (μm)	227	28.51	0.81	4.33	15.15§	18.18	41.20
Variability in fiber diameter (μm)○	227	11.19	0.94	3.16	28.24	5.99	22.64
% of true fibers	227	89.53	0.70	6.67	7.45	58.54	100.00
% of modulated fibers	227	5.93	2.00	4.88	82.29	0.00	23.45
% of heterotype fibers	227	4.38	2.17	4.55	103.88	0.00	32.91
Scales accumulation#	212	6.19	0.34	0.84	13.57	4.84	8.51
Heterotype fibers diameter	132	46.67	1.25	8.55	18.32	29.74	80.00
Modulated fibers diameter	170	65.79	1.74	14.12	21.46	36.64	111.56

*: Each observation on the fiber diameter, Variability in fiber diameter and Heterotype and Modulated fiber diameters is based on 200 fiber measurements; each observation on the Scales accumulation is based on 10 fiber measurements and observations on different fiber types percentage is based on at least 600 fiber measurements. §: Coefficient of variation between wool samples. ○: Coefficients of variation within wool samples. #: Number of scales in 100 μm length of fiber

Table 2: MSs and dfs for the measured wool traits

Variable	df	T1	T2	T3	T4	T5	T6
Herd	5	187.97*	60.41*	112.30*	175.48*	87.69*	1.34*
Sex	1	1.52	0.11	35.80	23.77	0.05	2.94*
Season	1	123.03*	45.09*	697.70*	203.64*	163.77*	49.99*
Age (year)	6	15.64	11.55	58.28	26.11	37.28*	0.33
Residual	213	14.53	8.61	37.96	17.81	16.70	0.42§

*: ($p<0.01$). T1- Fiber diameter (μm); T2- Variability in fiber diameter (μm); T3- % of true fibers; T4- % of modulated fibers; T5- % of heterotype fibers; T6- Scales accumulation. §: Residual's degree of freedom (df) for scales accumulation is equal to 198

The estimations of true, modulated and heterotype fibers percentage were 89.53, 5.93 and 4.38%, respectively. The percentage of true fibers in Naeini sheep is high and the percentages of modulated and heterotype fibers are low relative to the other Iranian breeds. The diameter means of heterotype and modulated fibers were 46.67 and 65.79 μm, respectively; which are responsible for the increase in mean and variation in fiber diameter.

The highest and the lowest coefficients of variation were related to heterotype and true fibers percentage, respectively. The greater variability in each trait means the greater opportunity for selection on that trait and higher responses to selection are expected for traits with higher variation. Thus, it seems that there would be a higher response to selection against modulated and heterotype fibers rather than selection for true fibers.

Fiber diameter and variability: Herd effect had a high significant influence on both fiber diameter and variety ($p<0.01$) (Table 2). Variation which is originated from herd effect refers to different environments between herds and differences in genetic base between herds (Atkins, 1990; Stobart, 1986).

Sampling season had a significant effect on both fiber diameter traits, as well ($p<0.01$). However, animal's age and sex had not any meaningful effect on these two traits ($p>0.05$). This statement is in consistent with the results of Robert and Parlier (1986), Drummond *et al.* (1982) and Ercanbrack and Knight (1985). Sampling season can be highly effective on fiber diameter mean and its variety within wool samples. Thus, sampling procedure should be take place within a specific period of time (month) and interference of wool samples from different seasons should be avoided.

Least square means of wool fiber diameter traits are presented in Table 3. Sex had no significant effect on fiber diameter and its variability, which is in agreement with the results reported by Hasani (1992) on Lori-Bakhtiari breed and Salehi and Taherpoor (1988) on Baloochi breed. In this study, the fiber diameter mean and within fleece diameter variability of ewes was numerically higher than for rams. This may be due to higher selection intensities achieved on rams. The main reasons for sex differences may be hormonal differences between two sexes and to the genes located on sexual chromosomes. So, it could be concluded that these possible effects have a minuscule effect on wool traits in Naeini sheep. It seems that ewes are under more metabolic stresses than rams (because of pregnancy and milk production) and therefore the availability of nutrients to wool follicles fluctuates. Thus, fiber diameter variation would be higher for ewes.

Wool fiber diameter and the variability in fiber diameter of staples sampled at December were higher than measurements on staples sampled at June (Table 3). Fibers have an annually growth period. Because of changes in nutritional state, the growth rate and diameter of fibers change. In good nutritional and environmental conditions the growth and diameter of wool fibers increase. In Iran's climates in which sheep herds are usually kept in postural circumstances and fed from pastures in most periods of the year; during spring and summer at which pastures are rich, the growth rate and diameter of fibers increase. While, fiber growth decreases in poor postural conditions at fall and winter; in such a condition diameter variation alongside fibers increases (Botkin *et al.*, 1988; Masters *et al.*, 1998).

Table 3: Results of the statistical analysis for the studied traits

Variable	N*	T1	T2	T3	T4	T5	T6 (N§) Mean
Total	227	28.51±0.71	11.19±0.87	89.53±0.65	5.93±1.73	4.38±1.95	(210) 6.10
Sex							
Ram	36	27.56±0.84^{a}	11.22±0.64^{a}	91.38±1.35^{a}	4.73±0.93^{a}	3.73±0.89^{a}	(31) 6.23^{a}
Ewe	191	27.80±0.45^{a}	11.16±0.35^{a}	90.21±0.73^{a}	5.68±0.50^{a}	3.77±0.48^{a}	(179) 6.08^{a}
Season							
December	191	28.71±0.45^{a}	11.82±0.35^{a}	88.33±0.74^{b}	6.54±0.51^{a}	4.94±0.49^{a}	(38) 5.94^{b}
June	36	26.64±0.83^{b}	10.56±0.63^{b}	93.27±1.33^{a}	3.87±0.91^{b}	2.55±0.88^{b}	(172) 6.85^{a}
Age(year)							
1	14	25.41±1.34^{b}	10.12±1.03^{a}	89.05±2.16^{b}	4.51±1.48^{abc}	6.39±1.43^{a}	(13) 6.28^{a}
2	40	27.61±0.69^{ab}	10.50±0.53^{a}	93.56±1.12^{a}	4.77±0.76^{ab}	1.90±0.74^{c}	(40) 6.22^{a}
3	72	27.65±0.61^{ab}	10.43±0.47^{a}	91.69±0.99^{ab}	5.12±0.68^{ab}	3.23±0.68^{bc}	(66) 6.22^{a}
4	32	28.33±0.77^{ab}	11.24±0.59^{a}	90.55±1.24^{b}	4.51±0.85^{bc}	4.50±0.82^{ab}	(29) 6.16^{a}
5	36	28.03±0.78^{ab}	10.98±0.68^{a}	92.71±1.26^{ab}	3.26±0.86^{c}	4.37±0.84^{ab}	(35) 6.11^{a}
6	17	28.00±1.10^{ab}	11.23±0.85^{a}	89.86±1.78^{b}	6.00±1.22^{ab}	3.00±1.18^{bc}	(13) 6.04^{a}
7	16	26.37±1.13^{ab}	10.40±0.87^{a}	90.62±1.83^{ab}	4.39±1.25^{abc}	4.62±1.22^{ab}	(14) 5.78^{a}
Herd							
1	33	25.79±0.94^{bc}	10.03±0.73^{c}	92.15±1.51^{ab}	2.45±1.04^{d}	4.99±1.00^{ab}	(31) 5.79^{b}
2	39	28.87±0.77^{b}	11.52±0.59^{b}	92.81±1.24^{a}	5.01±0.85^{bc}	2.08±0.80^{cd}	(39) 6.08^{ab}
3	41	25.18±0.75^{c}	9.71±0.58^{c}	90.79±1.22^{abc}	4.95±0.83^{bc}	4.05±0.81^{ab}	(41) 6.33^{a}
4	39	27.42±0.88^{b}	10.88±0.67^{bc}	91.64±1.42^{ab}	3.36±0.97^{cd}	3.85±0.94^{bc}	(36) 5.97^{ab}
5	41	31.31±0.78^{a}	13.13±0.60^{a}	88.21±1.25^{c}	5.99±0.86^{b}	5.85±0.83^{a}	(41) 6.37^{a}
6	34	27.50±0.85^{b}	11.89±0.65^{ab}	89.15±1.37b^{c}	9.47±0.94^{a}	1.67±0.91^{d}	(22) 5.88^{ab}

T1- Fiber diameter (μm); T2- Variability in fiber diameter (μm); T3- % of true fibers; T4- % of modulated fibers; T5- % of heterotype fibers; T6- Scales accumulation. *: Each observation on the fiber diameter and Variability in fiber diameter is based on 200 fiber measurements and observations on different fiber types percentage is based on at least 600 fiber measurements. §: Number of observations for the scales accumulation is different relative to the other five traits and each observation on the Scales accumulation is based on 10 fiber measurements. Means with different characters in each column are statistically significant

Ewes' pregnancies usually happen late in fall or early in winter and so ewes usually lamb in spring. This situation causes increase in competition between wool follicles and the other body tissues for nutrients. These factors together with day length and weather changes are responsible for seasonal changes in wool growth and diameter mean and variability (Botkin *et al*., 1988; Coop, 1986).

Although, age had not any significant effect on fiber diameter traits ($p>0.05$), both fiber diameter mean and variability in diameter increase from their minimums at yearling to age 4. Afterwards, fiber diameter mean decreases and diameter variability had a decrease from age 6 to 7 (Table 3). Bunge *et al*. (1996) considering 2 to 5 years old ewes, reported that 2 years old ewes produce fleeces with a smaller fiber diameter mean than ewes of the older ages ($p<0.05$). In early ages due to high competition between wool follicles and the other body tissues, the availability of nutrients to wool follicles becomes limited and as a consequence wool growth rate and fiber diameter mean decrease; but in later ages in which this competition decreases, there is no significant difference in fiber diameter mean (Botkin *et al*., 1988; Coop, 1986; Masters *et al*., 1998).

Percentage of different fiber types: Results of the analyses of variances and a comparison between least square means for the levels of each fixed effect are presented in Table 2 and 3, respectively for all of the traits. Herd effect had a significant influence on the percentage of all three kinds of fiber ($p<0.01$). This may be due to high genetic differences between herds, together with different nutritional states, weather and other environmental conditions between different herds.

Sampling season had a considerable effect on the percentage of true, heterotype and modulated fiber types ($p<0.01$). The estimated percentage of true fibers was higher at June rather than December. While the situation for heterotype and modulated fibers was vice versa, which is not really unexpected due to increase in the percentage of true fibers. The differences in the percentage of different fiber types caused a significant difference in fiber diameter mean between two seasons, because modulated and heterotype fibers have higher diameters than true fibers (Botkin *et al*., 1988; Coop, 1986; Stobart, 1986).

Animal's sex had no significant effect on the related traits ($p>0.05$). So, the percentage of different fiber types did not differ significantly between sexes (Table 3). However, the percentage of true fibers was higher and the percentages of two other kinds of fiber were lower in males, which may be due to higher selection for fiber diameter on this sex. The results of this study are in consistent with the reports of Hasani (1992) and Salehi and Taherpoor (1988) on Lori-Bakhtiari and Baloochi breeds, respectively.

Age effect was only effective on the percentage of heterotype fibers ($p<0.01$). The minimum and maximum percentage of heterotype fibers was related to 1 and

2 year of age, respectively. However, the situation for true fibers was vice versa. Also, no important differences observed between other ages. There was no definite trend for the percentage of modulated fibers by age, however, the minima and maxima was related to 5 and 6 year of age, respectively. In another research (Bunge *et al*., 1996), the percentage of unfavorable fibers (modulated and heterotype) had a decrease from the age of 2 to 3 and then increased from the age of 3 to 5. Lower percent of true fibers in early and late ages may be due to increase in modulated fibers in the fleeces. At yearling because some primary hairs are still available, the percentage of true fibers is low and in late ages due to erosion of follicles' ability, the percentage of true fibers decreases and the percentage of modulated fibers increases.

Scales accumulation: Results of the analysis of variance and mean comparisons for scales accumulation are presented in Table 2 and 3, respectively. Scales accumulation was estimated based on the number of scales per 100 μm length of fiber. It seems that lower scales accumulation is associated with finer fibers with better handle character (the relative softness of the wool).

Herd, sex and season had significant effects on scales accumulation ($p<0.01$); while, there was no significant effect for age. On average, the number of scales per length of fiber was higher for rams than ewes. Furthermore, scales accumulation found to be higher in summer (June) than in winter (December) samplings. Also, scales accumulation showed a decreasing trend by age.

Correlations between measurements: Table 4, shows the estimated phenotypic correlations between the studied traits. Correlations between fiber diameter and all of the other traits were positive, except for the percentage of true fibers. Negative correlation between fiber diameter and the percentage of true fibers is due to the low diameter of true fibers, which decreases the fleece fibers diameter mean. Due to high diameter of modulated and heterotype fibers, increase in their proportion increases the fiber diameter mean of fleeces. Thus, to decrease the fiber diameter mean, it is worthwhile to select against modulated and heterotype fibers. The positive correlation obtained between fiber diameter mean and variability indicates that by increasing diameter variability, fiber diameter mean increases too, which is supported by the other results (Botkin *et al*., 1988; Stobart, 1986; Edriss, 2003).

Variability in fiber diameter was correlated with modulated and heterotype fibers diameter and percentage, positively. However, correlation with the percentage of true fibers was negative. Scales accumulation had positive correlations with fiber diameter mean and the percentages of modulated and heterotype fibers, while correlation with the percentage of true fibers was negative. So, it seems that as % of true fibers decreases and % of modulated and heterotype fibers increases, the number of scales per specific length of fibers increases.

Table 4: Correlations between different wool measurements

Trait	T1	T2	T3	T4	T5	T6	T7
T2	0.67***						
T3	-0.39***	-0.50***					
T4	0.26***	0.46***	-0.69				
T5	0.28***	0.17***	-0.66***	-0.003			
T6	0.02	-0.02	-0.09	0.070	0.08		
T7	0.22**	0.23***	-0.07	0.010	0.11	-0.17*	
T8	0.26***	0.55***	-0.25***	0.250***	0.05	-0.13	0.28**

*: ($p<0.05$); **: ($p<0.01$); ***: ($p<0.001$). T1- Fiber diameter (μm); T2- Variability in fiber diam (μm); T3- % of true fibers; T4- % of modulated fibers; T5- % of heterotype fibers; T6- Scales accumulation; T7- Heterotype fibers diameter; T8- Modulated fibers diameter

The percentage of true fibers had negative correlations with diameters and percentages of modulated and heterotype fibers. Because of positive correlations between percentages of modulated and heterotype fibers with their diameters, as their proportions in the fleeces increase, their diameters and as a result the fiber diameter mean of fleeces increase too.

The percentage of true fibers is high and the percentages of modulated and heterotype fibers are low in Naeini sheep. Due to high diameter means of modulated and heterotype fibers, the decrease of their proportion in fleeces leads to a decrease in the fiber diameter mean and as a result to an increase in wool quality. Based on high coefficients of variation for modulated and heterotype fibers, it is recommended to select against these fiber types to increase the percentage of true fibers and decrease the fiber diameter mean and variability.

Herd and season effects were highly effective on the studied measures. Thus, herd management and choosing the optimum shearing time are important to improve the quality of wool needed for carpet and textile factories. Most of the wool quality traits were correlated positively together, which indicates that by detecting and selection on major traits, the others will improve as well. A low coefficient of variation was found for the scales accumulation. So, it seems that there would be a low response to selection for this trait. In addition, measuring scales accumulation is much cost and time consuming. So, it would not be necessary to include this parameter in breeding programs.

Based on the fiber diameter mean, Naeini sheep has a medium wool type which is suitable for fine-carpet and semi-fustian textiles. According to the standards proposed by Coop (1986), the minimum fiber diameter required for carpet wool is between 36 and 40 μm with 40% true fibers and 20% heterotype fibers. It seems that, more breeding programs would be necessary to decrease the fiber diameter mean and increase fiber uniformity to meet the qualifications for fine-textile industry.

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