Trop Anim Health Prod (2011) 43:1337–1343
DOI 10.1007/s11250-011-9862-9

Wool characteristics in the third generation of Arkharmerino × Ghezel and Arkharmerino × Moghani crossbreed sheep

Hadi Esfandyari · Ali Asghar Aslaminejad · Seyed Abbas Rafat

Accepted: 12 April 2011 / Published online: 3 May 2011

Abstract This investigation was conducted to evaluate the comparative productive performances and effect of some environmental factors on wool characteristics of Arkharmerino × Ghezel (Ar × Gh) and Arkharmerino × Moghani (Ar × Mo) crossbreed sheep. The mid-side fleece samples taken from animals during 2 years (2007–2008) were analyzed. Each sample was measured for average fiber diameter, fiber diameter variability, staple length, proportion of medullated fiber, proportion of kemp, and comfort factor. The comparative values for these fleece characteristics in F_3 generation Ar × Gh were 28.78±0.48 μm, 36.84±1.16%, 11.94±0.35 cm, 7.07±0.93%, 1.02±0.23%, and 68.93%, respectively; while those traits were 29.79±0.43 μm, 41.86±1.16%, 11.96±0.37 cm, 8.13±1.06%, 2.71±0.45%, and 63.33±3.66% for Ar×Mo, respectively. The effects of genotype, sex, birth type, and year of birth were analyzed. Genotype had a significant ($P<0.01$) effect on average fiber diameter and proportion of kemp, and Ar×Gh crossbreeds had lower diameter with less proportion of kemp. The two differences in fiber characteristics that were attributable to sex were fiber diameter variability and proportion of medullated fiber, and females had higher measure than males for both traits. Statistical analysis showed that crossbreeding with Arkharmerino generally had positive effects on the fleece favored to be used in the hand woven authentic carpet production.

Keyword Carpet wool · Arharmerino · Moghani · Ghezel · Crossbreed

Introduction

Sheep breeding has an important role in animal production in Iran. Sheep have the ability to transform forage of grasslands which are widespread in Iran, into valuable products such as meat, milk, wool, and skin. Sheep meat, milk, and products are valued and generally preferred commodities. The value of indigenous breeds is for their ability to perform well under poor feeding and management conditions, which is possibly due to their genetic make-ups that fit in the evolving environmental conditions (Yilmaz et al. 2003).

The indigenous Ghezel and Moghani sheep breeds are raised in the northwest region of Iran where these two sheep breeds have been known for more than a hundred years. The relatively more favorable topography and denser population have contributed to make the region as one of the most intensively cultivated area in the country. Therefore, sheep husbandry in this region must compete with crops. Moghani and Ghezel sheep which are adapted to the cold and mountainous climate conditions are fat-tailed coarse wool sheep compared with other indigenous breeds in the country. They have low quality fleece with high percentage of kemp and medullated fibers and the average of fleece weight is 1.1 kg. Arkhamerino breed is a fine wool breed that has been established at Kurminitsky Research Institute of Kazakhstan by crossing Arkhar rams and Merino ewes (1934–1950). The average staple length is 6.2–8.1 cm in different position of body. The average fiber diameter is 22.3 μm in ewes and 23.5 μm in rams.

H. Esfandyari (✉) · A. A. Aslaminejad
Department of Animal Science, Faculty of Agriculture,
Ferdowsi University of Mashhad,
Azadi Square, P.O. Box 9177948974, Mashhad, Iran
e-mail: Esfandyari.Hadi@gmail.com

S. A. Rafat
Department of Animal Science, Faculty of Agriculture,
University of Tabriz,
Tabriz, Iran

The greatest portion of the wool produced by the indigenous sheep breeds in Iran is coarse or mixed type of wool, which is used in the hand-woven authentic carpet production. It is reported that there are 240,000 hand-woven carpet production workbenches spread throughout the country and about 5.1 million m^2 hand-woven carpets are being produced annually. This is an important occupation particularly for the female workers living in rural areas. The authentic hand-woven carpet type of wool is preferred for coarser or mixed type as the coarser fibers help the thread to stand upright in the carpet (Demir and Baspinar 1992).

Although native breeds of Ghezel and Moghani produce wool that is useful for carpet section, non-uniformity of wool diameter along the staple and different position of body is highly varied, which is undesirable. In addition, these two breeds have potential to produce finer wool to reach fine carpet qualifications (Shodja et al. 2004). Crossbreeding with an exotic breed to achieve these goals was undertaken during 1999 in the region. The Ar × Gh sheep were produced from crossbreeding Arkharmerino as sire and Ghezel as dam breeds and the Ar × Mo sheep were produced from crossbreeding Arkharmerino as sire and Moghani as dam breeds (Farahvash et al. 2010). For the production of second generation of Ar × Gh, sires and dams were selected from F_1 generation of Ar × Gh and similarly for the production of second generation of Ar × Mo sires and dams were selected from F_1 generation of Ar × Mo (Mokhber 2005). The third generation of Ar × Gh and Ar × Mo was the outcome of crossing among F_2s of Ar × Gh and Ar × Mo, respectively.

Many crossbreeding experiments have been conducted to estimate genetic effects of breeds of sheep typically but not always, increasing lamb production as primary objectives (Wolf et al. 1980; Kempester et al. 1987). Nevertheless, comprehensive evaluation requires that other factors, such as wool production and quality, must also be considered. Wool is an additional source of income in most sheep operations and can represent 15–25% of gross income (Cedillo et al. 1977). Therefore, breed effects for trait that influence fleece value should be considered when selecting breeds for a crossbreeding system. Previous papers in this series have described wool characteristics of Ghezel and Moghani ewes when mated to Arkharmerino rams (Ar × Gh and Ar × Mo) (Farahvash et al. 2010). The present study was part of a general project to improve sheep production by crossbreeding with fine wool breeds in northwest of Iran, a region which borders Turkey in the west and Azerbaijan in the north. The objective of the current study was to evaluate wool characteristics of third generation of Ar × Gh and Ar × Mo and describing genetic and environmental effects on fiber qualities.

Materials and methods

The third generation of Ar × Gh and Ar × Mo crossbreed sheep were produced and maintained at the Khalat Poshan Research Station located in Tabriz (latitude=38°08′ N, longitude=046°17′ E), Iran. The region is located in a semi-arid land, with an average annual rainfall of 390 mm (range 250–600 mm), a mean daily temperature of 15.9°C in midsummer and 1.4°C in midwinter, and an average 11 days of snowfall and 160 ground frosts per year. The elevation is 1,364 m above sea level. The two genotypes were managed in the same flock on the station. Both males and females flocks were kept indoors during the winter months. Animals were fed ground alfalfa-sainfoin hay and concentrate mixture during winter while grazed on pasture during mils season. The forage in the grazing areas was unimproved and comprised mainly of rye grass (*Lolium perenne*), tall fescue (*Festuca arundinacea*), and subterranean clover (*Trifolium subterraneaum*). At the station, shearing was conducted annually at the end of June. Before shearing, wool samples were taken from the midside (from the rib region) of 154 Ar × Gh and 142 Ar × Mo crossbreed sheep as presented by sex and genotype in Table 1.

The following objective measurements were conducted on each sample using the referenced international or the national standard methods by Animal Fiber Technology Ltd, University of Tabriz, Iran. Each raw sample was measured for staple length (SL) by ruler on velvet and then blended, scoured, dried, and conditioned in a standard atmosphere (20±2°C and 60±2% RH) for other measurements. Fiber snippets of 2 mm length were cut with a heavy duty sectioning device (guillotine) and spread on an open glass slide. Then, the slides were analyzed by projection microscope (BK2 4014, with power zoom of 300×) according to American Society for Testing and Material (ASTM 1989a). The following traits were analyzed: Average fiber diameter (AFD, μm), fiber diameter variability (FDV, %), proportion of medullated fibers (PMF, %), proportion of kemp fibers (PK, %), and comfort factor (CF, %). After determination of average fiber diameter, fiber diameter variability, proportion of medullated, kemp, and comfort factor measured on the same prepared sample for each sheep. AFD is the most important trait in determining fiber quality. FDV is the CV of all fiber diameter measurements taken on the sample. Proportion of medullated fiber (% by number) is defined by projection microscope as the proportion of fibers with less than 60% hollow cannel in fibers (ASTM 1989b). Data for medullated fibers were only

Table 1 Number of F_3 crossbreed sheep by genotype and sex

Ar × Gh	Male	70
	Female	84
Ar × Mo	Male	71
	Female	71

analyzed in white- and lighter-colored samples because projection microscope seems to overestimate the proportion in colored fibers (Delgado et al. 1999). Kemp is a technical term referring to a fraction of medullated fibers. Proportion of kemps (% by number) is defined by projection microscope as the proportion of fibers with more than 60% medulla in fiber. The separate mention of kemps was established by the ASTM (1989b), which recognized kemp as the source of more visible problems in fiber processing than medullated fiber (McGregor and Butler 2004). The percentages of kemp, medulla, and comfort factor were determined by count of 1,000 fiber in each sample. Comfort factor (% by number) is the percentage of fibers less than 30 μm and is defined by projection microscope as the proportion of fibers with a diameter less than 30 μm (ASTM 1989b).

Traits were tested for normal distribution and transformed when necessary. Only comfort factor showed a normal distribution. A logarithmic transformation ($y = \log_{10}x$) was performed for AFD and SL, PK and PMF were transformed with the function of Box and Cox ($y = ((x^{0.2} - 1)/0.2) - 1$) (Delgado 2003). The following statistical model was used for estimation of fixed effects:

$$Y_{ijkl} = \mu + \mathrm{GP}_i + S_j + \mathrm{Tb}_k + \mathrm{Yb}_l + e_{ijkl}$$

where, Y_{ijkl} refers to an observation on an individual animal, μ is the constant common to all individuals, GP_i the fixed effect of genotype, i=1, 2 (Ar × Gh and Ar × Mo), S_j the fixed effect of sex, j=1, 2 (male, female); TB_k the fixed effect of birth type, k=1, 2 (single and twin); Yb_l the fixed effect of year of birth, l=1, 2 (2007 and 2008), and e_{ijkl} is the residual effect.

The general linear model procedure of SAS (SAS Institute Inc 2004, Cary, NC, USA) was used to calculate and separate means (Duncan's multiple range test) and least squares means for the six characteristics recorded.

Results

Comparison of results from the literature with the current results presented here is difficult. It is not always clear whether published figures come from complete or de-haired fleeces in the case of carpet wool breeds. In addition, definitions for some traits such as kemp or medullated fiber vary. Extreme care must be taken to select comparable datasets (Lupton et al. 2006). Mean, standard deviation, minimum, and maximum limits for measured traits (AFD, SL, FDV, PK, PMF, and CF) are presented by genotype (Ar × Gh and Ar × Mo) in Table 2. Average fiber diameter in Ar × Gh and Ar × Mo in third generation was 28.78 and 27.79 μm, respectively. The fiber diameter of two genotypes is intermediate and comparable to carpet-wool breeds, 31 μm for Barki sheep, 26.2 μm for Arabi sheep, 35.4 μm for Ossimi, and 31.5 μm for Rahmani (Tabbaa et al. 2001). Shodja et al. (2004) reported 34.7 and 27.53 μm for Ghezel and Moghani pure breeds, respectively. FDV in Ar × Gh and Ar × Mo was 36.84% and 41.86%, respectively. The FDV in carpet wool breeds varies considerably 27–55% and the present data falls within this range. Shodja et al. (2004) results for this trait in pure breeds were, 39.8% and 44.2%, respectively. The wide range in FDV in this study reflects the absence of selection for this trait in past generations. Notter and Hough (1997) reported FDV in Targhee sheep breed about 17.5%. It shows that FDV studied in crossbreeds are high and it must be reduced by selection.

Table 2 shows that staple length in Ar × Gh and Ar × Mo were 11.96 and 11.56 cm, respectively. The observed data in the present study is lower than the 13–20 cm range in carpet–wool breeds from other Middle Eastern countries. Shodja et al. (2004) reported staple length for Ghezel and Moghani breeds 12.37 and 11.72 cm, respectively. The 7.1% and 8.1% of PMF in the present study

Table 2 Mean, standard deviation, minimum, and maximum for wool characteristics measurements by genotype

Genotype	measurement	No.	Mean	SD	Min	Max
Arkharmerino × Ghezel	AFD (μm)	154	28.78	3.55	22.23	36.99
	FDV (%)	154	36.84	8.54	22.06	57.40
	SL (cm)	154	11.96	2.70	5	18.50
	PMF (%)	154	7.07	6.91	0	27.6
	PK (%)	154	1.02	1.73	0	8.1
	CF (%)	154	68.46	13.82	34.25	92.75
Arkharmerino × Moghani	AFD (μm)	142	27.79	2.83	23.62	35.71
	FDV (%)	142	41.86	10.35	18.72	67.66
	SL (cm)	142	11.56	2.24	7	16.10
	PMF (%)	142	8.13	5.80	0.62	31.4
	PK (%)	142	2.71	2.96	0	14.4
	CF (%)	142	63.26	11.7	35.71	87.64

AFD average fiber diameter (μm), *FDV* fiber diameter variability (%), *SL* staple length (cm), *PK* proportion of kemp (%), *PMF* proportion of medullated fiber (%), *CF* comfort factor (%)

was similar to that reported for two genotypes in F_2 generation (Mokhber 2005) and smaller than 9.42% and 18.36% in pure breeds of Ghezel and Moghani, respectively (Farahvash et al. 2010). Proportion of medullated fiber in fine wool breeds is about 0.1–0.5% (Lupton et al. 2004). Proportion of PK in Ar × Gh and Ar × Mo were 1.0% and 2.7%, respectively. The large variation in proportion of kemp fiber, an undesirable trait, however, demonstrates opportunity for improving Ar × Gh and Ar × Mo fleece qualities by intensive selection. The amount of medullated fibers in current study falls within the range of 5–25% reported for carpet–wool breeds in Asia (Mehta et al. 2004).

The importance of comfort factor relates to the feel of a fabric on a wearer's skin. Fabric made from wool with a high comfort factor (>95%) will have less rigid fibers that bend more easily and therefore feel less "prickly" (AWTA 2008). In the present study, comfort factor for Ar × Gh and Ar × Mo was 68.46% and 63.26%, respectively. Comfort factor is not regarded as a premium trait in carpet–wool and no comparable information available in literature. Nonetheless, it seems that comfort factor is little significance in carpet–wool sheep breeds due to coarser fibers in these breeds.

The values presented in Table 3 are least squares means of the untransformed data, the attached probabilities and tests relate to the transforms. This procedure was followed as back transformation of least squares means of transformed values is mathematically inappropriate. Influence of fixed effects (genetic group, sex, birth type, and year of birth) on wool traits was studied.

Discussion

Average fiber diameter

A large variance was found in literature regarding the fixed effects influences on fiber diameter. In the present study, genotype had significant effect ($P<0.05$) on average fiber diameter and Ar × Gh crossbreeds showed a significantly lower diameter than Ar × Mo but the difference was only about 2 µm. Brash et al. (1994), in evaluation of direct and maternal genetic effects on wool quality, reported that genotype had no effect on average fiber diameter. Lupton et al. (2004) compared wool of Dorset, Finnsheep, Romanov, Texel, and Monatadal crossbreds and indicated the effect of genotype on average fiber diameter. One explanation for the differences between two genotypes seems to be direct effects of Ghezel and Moghani breeds. Year of birth had a significant effect ($P<0.05$) on AFD. This result was in agreement with literature reports (Iniguez et al. 1998; Mokhber 2005). Animals which were born in 2007 had less AFD than animals which were born in 2008 (Table 3). Statistical results for the main effect of year of birth are presented simply to document magnitudes of annual variation for wool traits. Year of birth effects are not discussed further because conditions causing year differences are difficult to determine, future specific effects cannot be predicted, and it is appropriate for producers to make decisions about sire breeds, dam breeds, and shearing seasons based on information averaged over several years (Lupton et al. 2004). There was no significant effect of sex on AFD. Tabbaa et al. (2001) and Mehta et al. (2004)

Table 3 Least squares means, standard errors, and effect of factors affecting on fleece characteristics by genotype, sex, year of birth, and birth type

Subclass		No.	AFD (µm)	FDV (%)	SL (cm)	PK (%)	PMF (%)	CF (%)
Genotype			*	ns	ns	**	ns	ns
	Ar × Gh	154	27.29±0.66 a	39.05±2.26	11.96±1.24	1.26±0.49 a	2.23±0.25	68.93±2.66
	Ar × Mo	142	29.54±0.91 b	36.09±1.99	11.56±1.27	2.44±0.67 b	2.64±0.35	63.33±3.66
Sex			ns	**	ns	ns	**	ns
	Male	141	27.90±0.77	35.25±1.84 a	12.18±1.40	1.61±0.57	2.18±0.29 a	67.22±3.08
	Female	155	28.93±0.67	39.53±2.2 b	11.49±1.25	2.34±0.54	2.78±0.25 b	65.04±2.71
Year of birth			*	ns	**	ns	ns	ns
	2007	114	27.41±1.01 a	35.93±2.89	9.77±1.37 b	2.38±0.74	2.41±0.38	68.01±4.06
	2008	182	29.43±0.50 b	38.48±1.46	12.15±0.60 a	1.32±0.37	2.46±0.19	64.24±2.01
Birth type			*	*	**	ns	ns	ns
	Single	180	28.71±0.50	39.43 b±1.49	11.93 a±1.25	2.39±0.37	2.52±0.19	64.81±2.01
	Twins	116	28.12±1.02	35.72±3.01 a	11.03±1.42 b	1.31±0.75	2.35±0.39	67.45±4.10

In each of the subgroups, means followed by different letters differ significantly

AFD average fiber diameter (µm), *FDV* fiber diameter variability (%), *SL* staple length (cm), *PK* proportion of kemp (%), *PMF* proportion of medullated fiber (%), *CF* comfort factor (%), *ns* none significant

*$P<0.05$, **$P<0.01$

reported similar results for the effect of sex on AFD in Awassi and Magra breeds of sheep, respectively. Birth type affected ($P<0.05$) AFD in two genotypes and single-born animals had more fiber diameter than twins. Mokhber (2005) reported similar result for the effect of birth type on AFD in F_2 of crossbreeds.

Fiber diameter variability

Influence of fixed effects on FDV in F_3 of Ar × Gh and Ar × Mo was exactly the same as the results of Mokhber (2005) for F_2 of crossbreeds. Genotype did not affect FDV which is in agreement with the findings of Yilmaz et al. (2003). Sex ($P<0.01$) and birth type ($P<0.05$) had significant effect on FDV. Dashab et al. (2006) reported that sex had significant effect on FDV in Naeini sheep. FDV for female was higher than male and for singles was higher than twins. One of the main reasons for sex differences may be hormonal differences between both sexes and to the genes located on sexual chromosomes (Dashab et al. 2006). It seems that females are under more physiological stresses than males (because of pregnancy and milk production) and therefore the availability of nutrients to wool follicles fluctuates. Thus, FDV would be higher for females. Research has shown that FDV increases with fiber diameter (Rafat et al. 2007). So, it could be concluded that higher FDV in single-born animals is the outcome of their high fiber diameter in contrast with twin born animals.

Staple length

Genotype did not have significant effect on SL that is in agreement with Bunge et al. (1996) and Shodja et al. (2004). No differences between sexes could be found for SL. These results are in agreement with Wuliji et al. (2000), but contrary to other studies (Dick and Sumner 1996; Iniguez et al. 1998; Dashab et al. 2006). SL was effected by year of birth and birth type ($P<0.01$), significance of year of birth is in agreement with Lupton et al. (2004) and Mokhber (2005) and in disagreement with Sidwell et al. (1973). Animals which were born in 2007 had shorter SL from those born in 2008 and this difference was significant ($P<0.01$). As shown in Table 3, birth type had significant effects on SL ($P<0.05$) and singles had longer SL than twins It is possible that poor nutrition (especially for dams with twin lambs) during early postnatal life imposes a permanent limitation on fiber production ability and fiber diameter of lamb (Dick and Sumner 1996).

Proportion of kemp and medullated fibers

In the present study, kemp and medullated fibers are distinguished from each other. Some authors give the proportion of coarse hair and the diameter that goes with it (Wurzinger et al. 2005). Iniguez et al. (1998) defined kemp as proportion of fragmented and continuous medullated fiber. The results in Table 3 show a significant effect ($P<0.01$) of genotype on PK percentage in fleece. In this study, Ar × Mo crossbreeds had shown higher PK percentage than Ar × Gh. Çolakoglu and Özebyaz (1999) compared wool of Malya and Akkaraman sheep and indicated the effect of genotype on proportion of kemp. Shodja et al. (2004) reported that Moghani breed sheep has higher proportion of kemp than Ghezel, so it could be concluded that direct effect of Moghani has major influence on the differences between two genotype groups. Mokhber (2005) reported a similar result for the effect of genotype on PK in F_2 generation. There was no significant effect of sex, birth type, and year of birth on PK. These results were in agreement with the findings of Iniguez et al. (1998) and Wurzinger et al. (2005).

No difference was shown between genotype groups, year of birth, and birth type for medullated fibers (Table 3). However, proportion of medullated fibers was higher in Ar × Mo and single-born animals. These results are in agreement with Çolakoglu and Özebyaz (1999) and Tabbaa et al. (2001) but contrary to other studies (Çorekci and Evrum 2000; Lupton et al. 2006). Sex had a high significant effect ($P<0.01$) on PMF which is in agreement with the results reported by Lupton et al. (2004) on Dorset and Texel sheep breeds and Mokhber (2005) on Ar × Gh and Ar × Mo crossbreeds. Regarding Table 3, females had higher PMF than males (2.78% versus. 2.18%). This result can be attributed to delay in follicle maturation in females because females are under more physiological stresses than males. PMF in singles was measured higher than twins but this difference was not significant ($P>0.05$). Regarding higher AFD for singles than twins in this study is credible because high positive correlation also has been reported between AFD and PMF for these breeds (Safari et al. 2005).

Comfort factor

Comfort factor is an important trait for apparel textiles whereas coarse fiber (>30 μm) is responsible for the unwanted "prickle factor". Comparison of the comfort factor should be interpreted with care in carpet wool types. In the present study, the definition is valid for proportion of fibers with a diameter less than 30 μm. Tekin et al. (1998) define it as nonmedullated fiber and Martinez et al. (1997) as a combination of unmedullated and fragmented medullated fiber. None of the studied factors had any significance influence on comfort factor (Table 3). This trait has not been studied in carpet–wool breeds so, it is hard to discuss about validity or invalidity of given results. CF in Ar × Gh crossbreeds, males, and twins were higher than Ar × Mo, females, and singles, respectively, and these differences were not significant ($P>0.05$) but were logical because an increase of AFD and a simultaneous decrease in comfort factor have been reported (Martinez et al. 1997). In addition, high negative correlation has been reported among these two traits (Iniguez et al. 1998).

Conclusions

According to the results of this study, crossbreeding with Arkharmerino has shown favorable effect on wool characteristics improvement of Azerbaijan native breeds. Crossbreed sheep have shown to produce finer wool than native breeds with better uniformity. By conducting well-planned designs, crossbreeds can supply the wool needed for fine carpet industries. Improvements in management and breeding strategies should be carried out at the same time.

Acknowledgments The authors wish to thank the staff of the Khalat Poshan Research Station and Mr. Davood Teimoury for their invaluable research assistance and specific thanks to the reviewers and Dr. André de Almeida for their helpful suggestions and constructive comments which led to a substantial improvement of submitted manuscript.

References

ASTM, 1989a. Standard test method for diameter of wool and other animal fibers by micro projection, D2130-90.

ASTM, 1989b. Standard test method for med and kemp fibers in wool and other animal fibers by microprojection, D2968-83.

AWTA, 2008. Wool diameter: fact and fiction, Australian Wool and Textile Association, Available at www.awta.com.au.

Brash, L.D., Fogarty, N.M. and Gilmour, A.R., 1994. Genetic parameters for Australian maternal and dual-purpose meat sheep breeds. I. Live weight, wool-production and reproduction in Border Leicester and related types, Australian Journal of Agricultural Research, 45, 459–468.

Bunge, R., Thomas, D.L., Nash, T.G. and Lupton, C.J., 1996. Performance of hair breeds and prolific wool breeds of sheep in Southern Illinois: wool production and fleece quality, Journal of Animal Science, 74, 25–30.

Cedillo, R.M., Hohenboken, W. and Drummond, J., 1977. Genetic and environmental effects on age at first estrus and on wool and lamb production of crossbred ewe lambs, Journal of Animal Science, 44, 948–955.

Çolakoglu, N. and Özebyaz, C., 1999. Comparison of some production traits in Malya and Akkaraman sheep, Turkish Journal of Veterinary and Animal Science, 23, 351–360.

Çorekci, S.G. and Evrum, M., 2000. Comparative studies on the production performances of Chios and Imroz breeds kept under semi-intensive conditions II. Milk production, fleece yields and characteristics, Turkish Journal of Veterinary and Animal Science, 24, 545–552.

Dashab, G., Edriss, M.A., Ghare Aghaji, A.A., Movasagh, H. and Nilforoshan, M.A., 2006. Wool fiber quality of Naeini sheep, Pakistan Journal of Biological Sciences, 2, 270–276.

Delgado, J., 2003. Perspectivas de la producci´on de fibra de llama en Bolivia, (unpublished PhD thesis, University of Hohenheim).

Delgado, J., Valle Zarate, A. and Mamani, C., 1999. Fiber quality of a Bolivian meat-oriented llama population, Progress in South American Camelids Research, EAAP Publication No. 105, 2001, 101–109.

Demir, H. and Baspinar, H., 1992. Production performance of Kivircik sheep under semi-intensive conditions. 2. Fertility, milk production, body weight and wool characteristics of ewes. Journal of Faculty of Veterinary Medicine, University of Istanbul, 17 (2), 13–24.

Dick, J.L. and Sumner, R.M.W., 1996. Development of fiber and follicle characteristics related to wool bulk in Perendale sheep over the first year of life. Proceedings of the New Zealand Society of Animal Production, 56, 314–318.

Farahvash, T., Shodja, J., Rafat A. and Keshtkaran, A., 2010. The effect of bilateral crossbreeding between arkhamerino and ghezel sheep on the quality of wool of their F_1 crosses, Asian Journal of Animal and Veterinary Advances, 6, 397–400.

Iniguez, L.C., Alem, R., Wauer, A. and Mueller, J., 1998. Fleece types, fiber characteristics and production system of an outstanding llama population from Southern Bolivia, Small Ruminant Research, 30, 57–65.

Kempester, A.J., Croston, D., Guy, D.R. and Jones, D.W., 1987. Growth and carcass characteristics of crossbred lambs by ten sire breed, compared at the same estimated carcass subcutaneous fat proportion, Animal Production Science, 44, 83–98.

Lupton, C.J., Freking, B.A. and Leymaster, K.A., 2004. Evaluation of Dorset, Finnsheep, Romanov, Texel, and Montadale breeds of sheep: III. Wool characteristics of F_1 ewes, Journal of Animal Science, 82, 2293–2300.

Lupton, C.J., McColl, A. and Stobart, R.H., 2006. Fiber characteristics of the Huacaya Alpaca, Small Ruminant Research, 64, 211–224.

Martinez, Z., I˜niguez, L.C. and Rodr´ıguez, T., 1997. Influence of effects on quality traits and relationships between traits of the llama fleece, Small Ruminant Research, 24, 203–212.

McGregor, B.A. and Butler, K.L., 2004. Sources of variation in fiber diameter attributes of Australian alpacas and implication for fleece evaluation and animal selection. Australian Journal of Agricultural Research, 55(4), 433–442.

Mehta, S.C., Choprn, S.K., Singh, V.K., Ayub, M. and Mahrotra, V., 2004. Production and quality of wool in Magra breed of sheep, Indian Journal of Animal Science, 74 (7), 792–794.

Mokhber, M., 2005. Evaluation of wool characteristics of Arkharmerino × Ghezel and Arkharmerino × Moghani crossbreed sheep in second generation (MSc Thesis, University of Tabriz)

Notter, D.R. and Hough, J.D., 1997. Genetic parameter estimates for growth and fleece characteristics in Targhee sheep. Journal of Animal Science, 75, 1729–1737.

Rafat, S.A., Rochambeau, H.D, Brims, M., Thébault, R.G., Deretz, S., Bonnet, M. and Allain, D., 2007. Characteristics of Angora rabbit fiber using optical fiber diameter analyzer, Journal of Animal Science, 85, 3116–3122.

Safari, E., Fogarty, N.M. and Gilmour, A. R., 2005. A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep, Livestock Production Science, 92, 271–289.

SAS Institute Inc., 2004. SAS/STAT Software Release 9.1. SAS Institute Inc., Cary, NC.

Shodja, J., Farahvash, T. and Rafat, S.A., 2004. The evaluation of fleece characteristics in Arkharmerino × Moghani F_1 crossbreds, Proceedings of the 11th AAAP Animal Science Congress, Kuala Lumpour, 624–626.

Sidwell, G. M., Wilson, R. L. and Hourihan, M.E., 1973. Production in some pure breeds of sheep and their crosses. IV: effect of crossbreeding on wool production, Journal of Animal Science, 32, 1099–1102.

Tabbaa, M.J., Al-Azzawi, W.A. and Campbell, D., 2001. Variation in fleece characteristics of Awassi sheep at different ages, Small Ruminant Research, 41, 95–100.

Tekin, M.E., Gurkan, M. and Kadak, R., 1998. The wool characteristics of Akkaraman, Awassi and their F_1 and B_1 crossbreed with German Blackheaded Mutton and Hampshire Down breed, Journal of Animal Breeding and Genetics, 118, 92–94.

Wolf, B.T., Smith, C. and Sales, D.I., 1980. Growth and carcass composition in the crossbred progeny of six terminal sire breeds of sheep, Animal Production Science, 31, 307–313.

Wuliji, T.G., Davis, H.K., Dodds, G., Turner, P.R., Andrews, R.N. and Bruce, G.D., 2000. Production performance, repeatability and heritability estimates for live weight, fleece weight and fiber characteristics of alpacas in New Zealand, Small Ruminant Research, 37, 189–201.

Wurzinger, M., Delgado, J., Nurnberg, M., Valle Z´arate, A., Stemmer, A., Ugarte, G. and Solkner, J., 2005. Genetic and non-genetic factors influencing fiber quality of Bolivian llamas, Small Ruminant Research, 6, 131–139.

Yilmaz, A., Ozcan, M., Ekiz, B., Ceyhan, A. and Altinel, A., 2003. The body weights and wool characteristics of the indigenous Imroz and Kivircik sheep breeds of Turkey, Wool Technology and Sheep Breeding, 51(1), 16–23.