



Wool characteristics of Bakhtiari sheep and the correlated responses to selection for pre-weaning daily gain

SABA BEHDAD¹, MOHAMMAD A EDRISS ², MOHAMMAD A NILFOROOSHAN³ and AMIR H MOVASSAGH ⁴

Isfahan University of Technology, Isfahan, Iran

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ABSTRACT

The study was conducted to investigate whether selection on pre-weaning daily gain will affect wool production and its quality or not in Bakhtiari sheep. Sheep (150) were selected randomly to make 5 equal sized age groups from 1 to 5-year-old sheep, containing 5 rams and 25 ewes in each group. According to the standards of wool sampling from shoulder and side, these body parts were marked on each animal before shearing. According to the high percentage of true type fibres, to decrease fibre diameter, it would be more efficient to select directly on fibre diameter rather than selection for the percentage of true type fibres.

For fleece weight, all the studied effects were significant, with higher fleece weight for males than for females. The highest mean of fleece weight was for twin-born-weaned lambs and the lowest mean was for twin-born-single-weaned lambs. Fleece weight was the only wool characteristic affected significantly by rearing type. Fleece weight increased by age to 3 years and then decreased. For fibre diameter, body part, sex and age were the significant effects. Fibre diameter was thinner in shoulder than side and it was thinner for ewes than for rams. This shows, although ewes produced less wool than rams, their wool was of a better quality. Shoulder and side fibre diameter increased from yearling to 3 years and 4 years, respectively, and then decreased.

Bakhtiari sheep, a fat-tailed Iranian sheep, is a relatively large-sized breed distributed mainly in the south-western part of Iran. The typical appearance of the sheep is white, but black and brown animals are also found among the other Iranian breeds (Talebi and Edriss 1998, Edriss *et al.* 2002). Bakhtiari sheep is one of the most common native breeds of Iran adapted to harsh and rocky environments in the western and central parts of the country. The animals are mostly kept on rangeland by nomadic or transhumant pastoralists and small holders settled in villages (Edriss *et al.* 2002). Bakhtiari herds are mainly raised for meat production and the wool is used in carpet industry. Whereas selection is mainly on growth traits, the main belief is that it is unfavourably

correlated with wool quality characteristics. There have been some studies on growth traits of Bakhtiari sheep (Edriss *et al.* 2002, Sargolzaei and Edriss 2004). However, study on its wool characteristics is very limited. The aim of this study is to investigate how selection on pre-weaning daily gain will affect wool production and its quality.

MATERIALS AND METHODS

The studied population was the herd of Bakhtiari Sheep Breeding and Husbandry Station, located at Chahar-Mahal-Bakhtiari province, Iran. The herd is an open nucleus herd that exchanges sheep with most of the Bakhtiari herds in the province. At the time of recording (June 2010), the herd consisted of 81 rams and 452 ewes; from which 150 sheep were selected randomly to make 5 equal sized age groups from 1 to 5-year-old sheep, containing 5 rams and 25 ewes in each group. According to the standards of wool sampling from shoulder and side, these body parts were marked on each animal before shearing. After shearing and weighting greasy fleece of animals, the marked parts of shoulder and side were collected. Four staples were selected randomly from wool samples of each animal for measuring staple length based on millimeter scale.

In order to make samples prepared for wool quality studies, 5 g of each sample from each body part (shoulder, side) were packed in a fabric material, putted in a beaker containing 125 mg Flousoan soap, dissolved in 1000 ml water. Beakers were put in a bath 40°C for 20 min. Samples were washed in a cold water flow and dried in laboratory conditions for 1 week.

The percentage of different fibre types (including truetype, heterotype, and kemp) were estimated based on the

Present address: ^{1,2,4} Department of Animal Science (sababehdad@yahoo.com, edriss@cc.iut.ac.ir, movassag@cc.iut.ac.ir). ³ Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, Uppsala (Mohammad.Nilforooshan@hgen.slu.se).

classification of 600 fibres per wool sample, using an optical microscope. In order to measure the fibre diameter mean of each sample, 200 fibres were chosen randomly, fibres were cut vertically using a Microtome machine. Afterwards, the diameter of vertical cuts was measured using scaled optical lens and Image Tool software (Don *et al.* 1995).

Three statistical models were applied for different traits, and the analyses were carried out using SAS/STAT (1997).

The statistical model for fleece weight was:

$$Y_{ijklm} = \mu + S_j + A_k + S_j A_k + W_l + e_{ijklm}$$

The statistical model for percentages of different fibre types was:

$$Y_{ijkl} = \mu + R_i + S_j + R_i S_j + A_k + R_i A_k + S_j A_k + R_i S_j A_k + e_{ijkl}$$

The statistical model for fibre diameter and staple length was:

$$Y_{ijklm} = \mu + R_i + S_j + R_i S_j + A_k + R_i A_k + S_j A_k + R_i S_j A_k + W_l + e_{ijklm}$$

where Y is the measured record, μ is the population mean for that measurement, R, S, A, and W are the fixed effects of the sampling body part, sex, age group and rearing type, respectively, and e is the random residual effect.

To study the way that selection on pre-weaning daily gain is affecting wool traits, the correlated response to selection for pre-weaning daily gain in wool traits were estimated using the following formula (Falconer and Mackay 1996), assuming equal selection intensities:

$$CR/R = r_A'' h_1^2 / h_2^2$$

where CR/R is the correlated response to selection in trait 2 following direct selection on trait 1, r_A is the genetic correlation between the two traits, h_1^2 and h_2^2 are the heritabilities for trait 1 (the trait under direct selection; i.e. pre-weaning daily gain) and trait 2 (the correlated trait; i.e. any of the wool traits) respectively.

The objective of this study was to grade the wool of Bakhtiari sheep, estimating genetic parameters for some wool quality traits and pre-weaning daily gain, and predicting the correlated responses in wool quality traits for selection on pre-weaning daily gain in Bakhtiari sheep.

RESULTS AND DISCUSSION

The results of the analyses of variance for some wool characteristics are shown in Table 1, and the mean comparisons are shown in Table 2. For fleece weight, all the studied effects were significant, with higher fleece weight for males than for females. The highest mean of fleece weight was for twin-born-weaned lambs and the lowest mean was for twin-born-single-weaned lambs. Fleece weight was the only wool characteristic affected significantly by rearing type. Fleece weight increased by age to 3-year and then decreased (Table 2). For fibre diameter, body part, sex and age were the significant effects. Fibre diameter was thinner in shoulder than side and it was thinner for ewes than for rams. This shows, although ewes produced less wool than rams, their wool was of a better quality. Shoulder and side fibre diameter increased from yearling to 3-year and 4-year, respectively, and then decreased. Sex, age and their interaction significantly influenced staple length (Table 1). Table 2 shows that staple length was the longest in 4-year animals and also rams produced significantly ($P < 0.001$) longer staples than males.

The results on the percentage of different fibre types (Tables 1 and 2) showed that those were significantly different between shoulder and side. The percentage of true type fibres was higher in the shoulder part and the percentage of heterotype and kemp fibres were higher in the side part. These results supported the observed differences between shoulder and side parts regarding fibre diameter. Sex was also significant on the percentage of true type and heterotype fibres, and slightly effective ($P < 0.1$) on the percentage of kemp fibres. The differences between shoulder and side regarding the percentage of fibre types were less in ewes than rams (Table 2). Age and its interaction with the other effects (body part, sex, and body part $\times$ sex) were significant for the percentage of true type and heterotype fibres, while for the percentage of kemp fibres, only the interaction of age $\times$ sex was significant ($P < 0.05$). The percentage of fine

Table 1. Results of the analyses of variances (including mean of squares) for the studied wool characteristics of Bakhtiari sheep

Effect	Fleece df	Fibre weight (kg)	Staple		Fibre type		
			Diameter (μ m)	Length (mm)	%true	%hetero	%kemp
Part	1		313.56*	57.96	1 237.32***	260.09 **	367.51 ***
Sex	1	6.72***	915.07***	8 497.59***	640.78**	179.85 *	85.9
Sex $\times$ Part	1		4.22	108.6	214.34	77.34	6.04
Age	4	1.99***	136.17*	3 837.60***	305.86 **	127.25 **	39.71
Age $\times$ Part	4		49.95	73.77	345.66 **	89.43 *	13.35
Age $\times$ Sex	4	1.94 ***	70.9	2 371.77**	478.30 ***	136.19 ***	83.24 *
Age $\times$ Part $\times$ Sex	4		37.5	141.73	282.67 **	109.83 **	24.18
Weaning type	2	0.88 *	94.23	198.3			
Residual	#	0.21	65.39	586.32	76.37	28.81	27.38
C.V.		22.82	22.03	18.8	9.71	109.3	102.44

#: 138 for fleece weight, 275 for fibre diameter and staple length, and 277 for fibre type. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 2. Mean comparisons for the studied wool characteristics of Bakhtiari sheep

Effect		N #	Fibre diameter (μm)	Staple length (mm)	Fleece weight (kg)	% True type	% Heterotype	% Kemp	
Part		Shoulder	150	36.78 ^b ±1.44	138.31 ^a ±4.31		91.84 ^a ±1.15	4.30 ^b ±0.71	3.74 ^b ±0.69
		Side	150	40.10 ^a ±1.441	36.88 ^a ±4.31		85.26 ^b ±1.15	7.32 ^a ±0.71	7.33 ^a ±0.69
Sex	Ram	Shoulder	25	39.42 ^{ab} ±2.23	145.96 ^a ±6.67	2.66 ^a ±0.14	90.84 ^{ab} ±2.17	4.73 ^b ±1.33	4.38 ^{bc} ±1.30
		Side	25	43.12 ^a ±2.23	146.49 ^a ±6.67		81.53 ^c ±2.17	9.39 ^a ±1.33	8.42 ^a ±1.30
	Ewe	Shoulder	125	34.14 ^c ±1.22	130.65 ^b ±3.64	1.97 ^b ±0.09	92.83 ^a ±0.79	3.87 ^c ±0.49	3.10 ^c ±0.47
		Side	125	37.07 ^b ±1.22	127.28 ^b ±3.64		89.00 ^b ±0.79	5.24 ^b ±0.49	6.23 ^{ab} ±0.47
Age	1-year	Shoulder	30	34.77 ^b ±1.83	129.66 ^b ±5.48	1.85 ^c ±0.12	89.13 ^{ab} ±1.65	4.57 ^c ±1.02	3.67 ^b ±1.02
		Side	30	36.74 ^b ±1.83	128.66 ^b ±5.48		89.84 ^{ab} ±1.65	3.94 ^c ±1.02	6.82 ^a ±0.99
	2-year	Shoulder	30	34.20 ^b ±2.14	126.10 ^b ±6.41	2.34 ^b ±0.13	92.06 ^{ab} ±2.14	4.82 ^{bc} ±1.31	3.56 ^b ±1.28
		Side	30	40.18 ^{ab} ±2.14	125.70 ^b ±6.41		87.86 ^b ±2.14	5.30 ^{bc} ±1.31	9.40 ^a ±1.28
	3-year	Shoulder	30	39.15 ^{ab} ±2.46	134.71 ^b ±7.36	2.74 ^a ±0.15	90.86 ^{ab} ±2.35	5.92 ^{bc} ±1.44	4.31 ^b ±1.41
		Side	30	40.51 ^{ab} ±2.46	138.54 ^b ±7.36		74.43 ^c ±2.35	12.77 ^a ±1.44	8.09 ^a ±1.41
	4-year	Shoulder	30	37.94 ^{ab} ±3.13	164.06 ^a ±9.39	2.27 ^b ±0.18	91.72 ^{ab} ±3.20	3.85 ^c ±1.97	5.14 ^{ab} ±1.92
		Side	30	45.04 ^a ±3.13	161.21 ^a ±9.39		5.59 ^{bc} ±1.97	8.26 ^a ±1.92	2.38 ^{ab} ±0.18
	5-year	Shoulder	30	37.84 ^{ab} ±3.13	136.99 ^b ±9.38	86.25 ^b ±3.20	95.42 ^a ±3.20	2.34 ^c ±1.97	2.00 ^b ±1.92
		Side	30	37.99 ^{ab} ±3.13	130.29 ^b ±9.38		8.97 ^{ab} ±1.97	4.06 ^b ±1.92	2.26 ^a ±0.06
Weaning Type [§]	SS	Shoulder	113	36.78 ^b ±1.12	135.39 ^a ±3.34	87.93 ^{ab} ±3.20			
		Side	113	39.77 ^{ab} ±1.12	135.32 ^a ±3.34				
	TS	Shoulder	25	37.98 ^{ab} ±2.22	137.47 ^a ±6.65	1.98 ^b ±0.12			
		Side	25	43.48 ^a ±2.22	131.95 ^a ±6.65				
	TT	Shoulder	12	34.72 ^b ±4.30	152.51 ^a ±12.85	2.70 ^a ±0.24			
		Side	12	37.91 ^{ab} ±4.30	132.92 ^a ±12.85				
Total			300	36.70±8.06	128.78±24.19	2.38±0.56	89.99±8.74	4.91±5.37	5.11±5.23

§: SS, born and weaned single; TS, born twin and weaned single, TT, born and weaned twin. Means with different letters are significantly different ($P < 0.05$). #: Each observation is based on 6 and 200 fibre measurements for staple length and the other traits respectively.

fibres (true type) was higher and the percentages of both heterotype and kemp fibres were lower for ewes than for rams. It was in accordance with the results obtained for fibre diameter. No clear pattern could be found for the percentages of different fibre types by age (Table 1), probably due to the significant interactions that age had with the other effects. Estimated heritabilities, genetic correlations, environmental correlation and correlated responses to selection (for pre-weaning daily gain) for the studied wool characteristics of Bakhtiari sheep are shown in Table 3. Fig. 1 shows the differences between different rearing types and sexes for pre-weaning daily gain.

According to the standards of wool quality (Coop 1986), fibre diameter of Bakhtiari sheep's wool falls in a suitable range for carpet wool, which is between 36 and 40 μm . However, it should be considered that because this nucleus herd has been under a designed selection programmes for improving wool quality, the fibre diameter of other Bakhtiari herds may not be very qualifying. Genetic exchange between this nucleus herd and the other herds may improve the genetic potential of this breed for wool quality.

Due to the importance of meat production and a considerably higher price of meat relative to wool in Iran, wool production has always remained as a byproduct of sheep enterprises. Therefore, planned/unplanned selection has mainly focused on meat production, both for pre-weaning

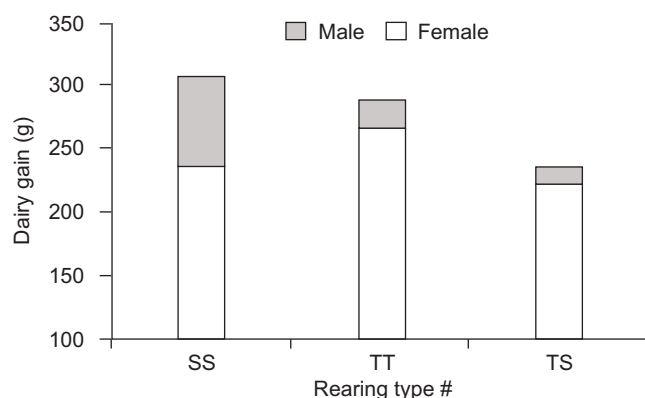


Fig. 1. Mean comparisons for pre-weaning daily gain (g) of Bakhtiari lambs. #: SS, born and weaned single; TT, born and weaned twin; TS, born twin and weaned single. The differences between SS-Rams with SS and TS-Ewes were significant ($P < 0.01$).

and post-weaning periods. One of the aims of this study was to investigate how selection on pre-weaning daily gain will affect wool production and its quality. To do this, the correlated responses to selection for wool traits based on selection for pre-weaning daily gain were studied. First, the heritabilities and genetic correlations were estimated by a multi-trait (5 traits) analysis of pedigree and performances using DFREML package (Meyer 1998) and then correlated responses to selection were estimated. The related results

Table 3. Estimated heritabilities, genetic correlations, environmental correlation and correlated responses to selection (for pre-weaning daily gain) for the studied wool characteristics of Bakhtiari sheep

Correlated trait	h^2	r_g	r_e	CR/R
Pre-weaning daily gain (g)	0.57±0.38	1	1	100
Fleece weight (kg)	0.09±0.39	-0.33±1	0.17±0.43	-83
Fibre diameter (µm)	0.61±0.37	-0.51±0.47	0.80±0.91	-49
Staple length (mm)	0.36±0.33	0.06±0.60	-0.04±0.48	7.5
%true fibres	0.34±0.38	0.55±0.67	-0.40±0.59	71

h^2 , heritability; r_g , genetic correlation; r_e , environmental correlation; CR/R, % correlated response to selection for the trait based on selection on pre-weaning daily gain.

are shown in Table 3. All the studied traits, except fleece weight had relatively high heritabilities, which means that there is a good potential for selection and genetic improvement in Bakhtiari sheep for these traits. The estimated heritability of pre-weaning daily gain in this study (0.57±0.38) was higher than the estimated heritability for Mehraban sheep (0.33±0.04; without considering maternal effects in the model of evaluation) that mainly exists in the west part of Iran (Mohammadi and Edriss 2007). The average pre-weaning daily gain of the herd (246 g/d) was also higher than the average pre-weaning daily gain of Mehraban sheep (197 g/d), reported by Mohammadi and Edriss (2007). The residual correlations with pre-weaning daily gain were of the opposite direction to the genetic correlations, which means that there are some environmental effects (e.g. nutrition) acting in the favour of both traits. The estimated correlated responses to selection (Table 3) showed that if selection is based on pre-weaning daily gain, the correlated responses would be -83%, -49%, 7.5% and 71% in fleece weight, fibre diameter, staple length and true fibres. Hopefully, selection on pre-weaning daily gain could also improve wool quality, which can be explained as a part of reduction in fleece weight according to the reduction in fibre diameter. However, gathering data on more animals and generations would be required to get more precise values with lower standard errors.

Edriss *et al.* (2002) reported a pre-weaning daily gain of 251.4 for Bakhtiari sheep, which was close to the report in the current study. They concluded that pre-weaning daily gain is under the influence of birth year, dam's age, sex of the lamb and birth type. Twin-born-single-weaned lambs had the lowest gain with the lowest difference between male and female lambs. Presumably, there were some problems on the maternal ability of the ewe for these kinds of lambs, which justifies the fail in survival of one of the twin-born lambs. The highest daily gain for females was for twin-born-weaned lambs, whereas the highest daily gain for males was for

single-born-weaned lambs. It shows that Bakhtiari male lambs gain less in more competitive conditions than female lambs. Wool fibres of Bakhtiari sheep was coarser than wool fibres of Naeini sheep, which is another Iranian breed more renowned for its good wool quality (Dashab *et al.* 2006). Dashab *et al.* (2006) reported no significant effect of sex and age on fibre diameter of Naeini sheep.

The percentages of different fibre types were close to the reported values for Naeini sheep (Dashab *et al.* 2006). Sex was not found to be a significant effect on the percentages of different fibre types for Naeini sheep and age was only significant on the percentage of heterotype fibres (Dashab *et al.* 2006).

In conclusion, According to the high percentage of true type fibres, in order to decrease fibre diameter, it would be more efficient to select directly on fibre diameter rather than selection for the percentage of true type fibres. The genetic correlations among traits together with the economic value of the traits should be considered in designing selection strategies. The authors also found it interesting to study correlated responses to selection for post-weaning growth to see whether it has any negative effect on wool production and its quality.

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