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Selection Indices for Improvement of Body Weight and Mohair Yield under the Traditional Low-Input Production System of Local Markhoz Goat in Iran

Research Article

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ABSTRACT

This research aimed to evaluate alternative selection schemes through their expected selection responses and the Bulmer parameters in the Markhoz goat breed. To select the best-ranked animals the body weights at birth, weaning, 6 months, 9 months, yearling, and mohair production records were assessed to compare the selection responses using SelAction 2.2. The average economic gain of the 3-trait indices was higher than the 2-trait indices. In this regard, the use of two selection indices of I7 (3-traits) and I4 (2-traits) promoted simultaneous improvement in both meat and mohair productions and can be proposed for application in this population. Artificial selection through several selection schemes has reduced population parameters in the current population of Markhoz goats. The magnitude of reduction in phenotypic variance and heritability was greater in traits that have been directly selected (included in index) and traits that had a higher economic coefficient in the index. Considering the present conditions, provided the optimal possible selection response, genetic improvement, and economic gain to improve both mohair and meat production. Although, the use of these indices depends on the determination of objectives and of the measurement facility of selection criteria.

KEY WORDS genetic evaluation, Markhoz goat, meat, mohair selection index.

INTRODUCTION

Markhoz goats have been distributed for years in Iran. Currently, a decreasing number of them can be found sporadically in certain parts of Kurdistan and West Azerbaijan provinces in Iran (Rashidi *et al.* 2011). The Markhoz goat is considered a multi-purpose animal, due to its meat, milk, and mohair production (Rashidi *et al.* 2011; Kheirabadi and Rashidi, 2016; Nazari-Ghadikolaei *et al.* 2018). Unfortunately, this breed with its unique mohair production in different colors is endangered. The profitability of Markhoz goats is feasible through genetic improvement in economic and strategic traits such as body weight and Mohair production.

The main goal in breeding plans is to increase the efficiency of the production system by selecting animals whose progeny will increase the profitability of the herd (Dubeuf and Boyazoglu, 2009; Theodoridis *et al.* 2018;

Simões *et al.* 2020; Rezende *et al.* 2021). Since the economic efficiency in animal breeding systems usually depends on more than one trait sometimes with unfavorable correlation among traits, in order to maximize net profit, multi-trait selection should be considered (Villanueva *et al.* 1993; Sölkner *et al.* 2008; Jahufer and Casler, 2015; Barwick *et al.* 2018).

Different methods have been introduced for a simultaneous selection of several traits among them, the selection index method or the total score was known as the most beneficial and optimal method for selecting several traits simultaneously and maintaining sustainability in livestock industries (Hazel *et al.* 1994; Dekkers, 2007).

Optimizing economic efficiency and maintaining the level of inbreeding in the herd depends on the completion of pedigree structure analysis, accurate genetic evaluation, updated estimation of the traits' economic values, phenotypic and genotypic relationships among the traits of interest, and attention to the genetic contribution and effective population size during the breeding plan (Rutten *et al.* 2002; Wellmann, 2019; Pook *et al.* 2020; Xu, 2022). One study on Ethiopian Begait goats revealed that there was close unison between the farmers' and bio-economic ranking. It was indicated that farmers could improve their goat's performance and their farm's profitability by selecting four strategic traits of 6-month weight, litter size, kid survival rate, and milk yield (Abraham *et al.* 2018). Moreover, another research indicated that goat breeding objectives in the drylands of North Kordofan, Sudan should be focused on milk production (El-Hag *et al.* 2020).

Despite the importance of Markhoz goats, there is no formal breeding objective for this breed. The objective of the present study was to identify the breeding objective with different selection indices for developing breeding programs considering mohair production alongside meat production in Iranian native Markhoz goats.

MATERIALS AND METHODS

Experimental data

In the present research, pedigree information and individual records of birth, weaning, market age (around 6 months), 9 months, yearling weight, and the mohair production weight of Markhoz goats were available for 25 years in the Markhoz goat breeding station located in Kurdistan province (5508 goats). The total livestock in the data file included 5508 Markhoz goats from 261 sires and 1615 dams. No special diets were used In all rearing periods and rearing was based on pasture and oak leaves in an open breeding system.

The information included the animal ID, parents of the animal, year of birth, gender, type of birth, the age of dams upon the birth of the kids, and individual records related to the above-mentioned traits descriptive statistics of the investigated traits are shown in Table 1.

Table 1 Pedigree structure of the studied goats

Source	№	Source	№
All goats	5508	Founders	349
Inbreed animals	3149	Non-founders	5159
All sires	261	Full-sib groups	1068
All dams	1615	Average family size	2.134
Goats with progeny	1876	Maximum family size	5
Goats without progeny	3632	Minimum family size	2
Average of inbreeding	0.05251		

Pedigree structure

An analysis of the pedigree structure was done in CFC (Sargolzaei *et al.* 2006). The family structure was assessed from different points of view (Razmkabir and Mahmoudi, 2019) such as the group composition in the pedigree, inbreeding coefficients, and the distribution of animals with different ancestral paths and the outcome are gathered in Table 1.

Genetic parameters and genetic evaluation

To ensure that the value of final estimations of phenotypic and genotypic variances, heritability, genetic and phenotypic correlations of the traits. corresponded to the absolute maximum of the likelihood function initial parameters were estimated from the individual performance and whole pedigree records using the DMUai package of DMU (Madsen *et al.* 2006).

For the breeding value estimation, an iteration-based method of Symmetric SOR Conjugate Gradient (SSORCG) (Dostál and Pospíšil, 2018; Vandenplas *et al.* 2020) was used for BLUP in the DMU4 package of DMU version 6 (Madsen *et al.* 2006). Here is the mixed model equation for estimating breeding values (BV):

$$Y_i = X_i b_i + Z_i u_i + e_i$$

For a multi-trait EBV model, the vector y which represents multi traits are including n1 observations for trait 1 (y1), and n2 observations for trait two (y2), and so on. Where there are 4 fixed effects (p_{1-4}) (birth year, age of dam, birth type and gender) associated with trait i_{th} so that X is a matrix with n_i x p_i dimensions and b_i is a p_i x 1 vector. X_i and Z_i are incidence matrices for fixed effects and random effects for traits, respectively.

Economic weights

In this study, the economic weights of similar traits of Iranian Rayeni goats were used as absolute economic coefficient (weights) or AEC of the Markhoz goat's traits (Kargar Borzi *et al.* 2017).

These economic weights of traits measure the gain in economic efficiency or the net income in dollars for a one-unit increase in the traits of interest. The relative economic coefficients (REC) of traits were expressed relative to the highest economic value of the traits (body weight at 6 months) that was set equal to 1. The relative importance (RI) of the traits was obtained by expressing the economic value of each trait with respect to the summation of the economic values of all included traits. Therefore, absolute economic (AEC), relative economic coefficient (REC), and relative importance (RI) for each trait of interest in Markhoz goat are represented in Table 2.

Table 2 The absolute economic coefficients, relative economic coefficient, and relative importance of the traits of interest in Markhoz goat

Trait	AEC ($)	REC	RI
BW	0.10	0.018	0.89
WW	3.00	0.53	26.8
W6	5.66	1	50.58
W9	1.50	0.26	13.40
W12	-0.87	-0.15	-6.97
Mohair	1.71	0.30	15.28

AEC: absolute economic weights ($) are according to Kargar Borzi *et al.* (2017);
REC: relative economic coefficient and RI: relative importance.
BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight.

Breeding goal and selection indices

Usually, goat farmers have multiplex preferences which affect the selection criteria. However, selling live goats, meat, and mohair for income generation were found as the main production objective of Markhoz goats (Kheirabadi and Rashidi, 2016; Kheirabadi and Rashidi, 2019; Razmkabir and Mahmoudi, 2019). Body weights at birth, weaning, market age (around 6 months), 9 months, yearling, and mohair in different 2 and 3 combinations were recognized as the traits in different indices with their corresponding economic coefficients (Mueller *et al.* 2015; Simões *et al.* 2020; Chomchuen *et al.* 2022).

Breeding program and genetic improvement

A selection index was used for simultaneously selecting several traits (Thompson and Meyer, 1986; Conington *et al.* 2001). The breeding objective was designed to maximize genetic gain for body weight and mohair yield in Markhoz goats. In the current study, the *SelAction 2-2* (Rutten *et al.* 2002) was used to optimize breeding programs based on the selection index theory, which maximizes genetic improvement toward breeding objectives by adding and formulating total scores for a multiple traits of body weights at different ages, and mohair yield using the male and female animals with the highest EBV which were selected from. the animals of last three years of pedigree (349 goats). The *SelAction* (Rutten *et al.* 2002) was used to predict the selection response, and the Bulmer equilibrium parameters (Hill *et al.* 2008; Van Grevenhof *et al.* 2012). In the present research with overlapping generations, the genetic parameters of the selected parents were determined in each age-class. Subsequently, the updated genetic variances/covariances were calculated as the weighted variance of age-classes, and repetitions continued until the Bulmer equilibrium was maintained (Rutten *et al.* 2002). The relationship between animals were considered by grouping them into different full-sib and half-sib families according to have one or two common parents. The effect of the correlation between full and half-sib' index values on selection intensity was calculated through selection index equations in each age-class. Then, selection intensity was adjusted for each age-sex class. Finally, the selection response in each breeding strategy was calculated using the adjusted selection intensity (Rutten *et al.* 2002).

RESULTS AND DISCUSSION

The aim of the present study was to describe a breeding goal to improve both meat and mohair productions and determine the most efficient selection index in Markhoz goats using pedigree data. Descriptive statistics of body weights at birth, weaning, market age, 9 months, yearling, and mohair yield are presented in Table 3.

Table 3 Descriptive statistics of 6 studied traits

Trait	N-Obs	Mean (kg)±SD	Min.	Max.
BW	5157	2.49±0.46	1.10	3.90
WW	3908	15.50±4.33	7.00	31.00
W6	3521	18.01±4.23	9.00	35.00
W9	3061	21.45±4.86	11.00	36.50
W12	2766	25.76±6.40	14.00	45.00
Mohair	2438	0.390±0.14	0.101	0.80

BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight.
N-Obs: number of records.
SD: standard deviation.

Genetic parameters and genetic evaluation

Phenotypic and genotypic variances, heritability, and the genetic and phenotypic correlation among traits are provided in Table 4.The maximum and minimum heritability were estimated for the 12-month weight (0.300) and mohair weight (0.167) respectively. Also, the maximum and minimum phenotypic variances were observed in 12-month (24.07) and birth weights (0.152), respectively.

Breeding goal and selection indices

A breeding objective is generally not fixed but specific to a particular strategy or local market; consequently, it is necessary to understand market and consumer preferences (Burns *et al.* 2022; Tyasi *et al.* 2022) (here the improvement of both meat and mohair production).

Table 4 Estimated genetic parameters, genetic correlation (below diagonal), phenotypic correlation (above diagonal), and the trait heritability (on diagonal) in multiple trait model

Trait	BW	WW	W6	W9	W12	Mohair
BW	0.272	0.098	0.151	0.137	0.119	0.027
WW	0.428	0.181	0.787	0.626	0.533	0.194
W6	0.400	0.973	0.187	0.819	0.665	0.210
W9	0.298	0.831	0.932	0.281	0.796	0.221
W12	0.344	0.682	0.822	0.947	0.300	0.208
Mohair	-0.013	-0.107	-0.093	-0.110	-0.137	0.167
σ^2_a	0.04±0.005	2.24±0.39	2.35±0.41	4.52±0.62	8.11±1.11	2.96±0.59
σ^2_e	0.11±0.004	9.91±0.35	9.89±0.37	10.61±0.49	15.96±0.83	14.04±0.58

BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight.
σ^2_a: additive variance and σ^2_e: residual variance.

In this situation, parents of the next generation were selected based on the highest EBVs of2 and 3 traits in DMU (Bett *et al.* 2007; Scholtens *et al.* 2020). The parameters related to our breeding goal were predicted based on different selection indices, in which the response rate of selection, the genetic and economic gains in males and females, and three different age groups were obtained and combined.

The following equation expresses our breeding goal. Moreover, relative weights for traits which were included in each selection indices (I1-I10) are described in Figure 1.

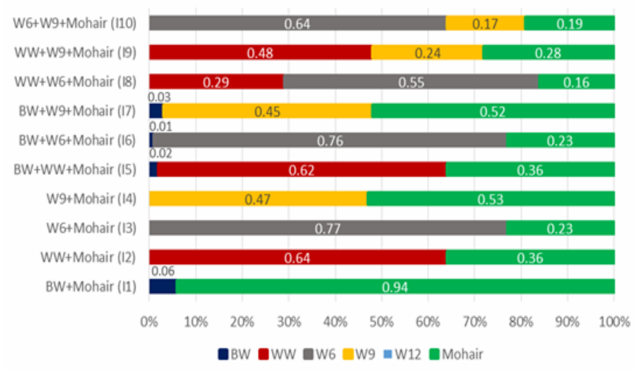

Figure 1 Relative weights for traits included in each selection indices (I1-I10)
BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight

$$H = a_{BW} \times BV_{BW} + a_{WW} \times BV_{WW} + a_{6W} \times BV_{6W} + a_{9W} \times BV_{9W} + a_{12W} \times BV_{12W} + a_{MO} \times BV_{MO}$$

Where:
H: breeding goal.
a: economic weight of the indexed trait.
BV: genetic merit of the indexed trait.

Breeding program

Choosing the best breeding plan among several available alternatives require a well-defined breeding objective to evaluate their efficiency. Furthermore, optimizing a breeding program requires that alternative equations be compared and evaluated (Rutten *et al.* 2002; Pook *et al.* 2020; Getachew *et al.* 2022). Therefore, a total number of 10 different selection equations strictly considers both body weights and mohair production traits including a set of two-trait equations with 4 correlated responses, and a set of three-trait equations with three correlated responses were evaluated. In all selection indices, population structure and selection intensities were considered the same for performing estimations till the results can be comparable. Finally, for optimizing genetic contribution to control inbreeding the number of male and female selection candidates per dam adjusted to be 1. Population size and selected proportion of parents are shown in Table 5. Selection indices were surveyed from the perspective of a selection response (genetic gain and economic gain), breeding goal variance, and Bulmer parameters.

Table 5 Population size and selected proportion of parents

Population	Size
Selected male parents	10
Selected female parents	55
Male selection candidates per dam	1
Female selection candidates per dam	1
Selected proportion male parents	
Age class 1	0.007×1.0= 0.007
Age class 2	0.350×5.0= 1.750
Age class 3	0.028×4.0= 0.112
Selected proportion female parents	
Age class 1	0.029×5.0= 0.145
Age class 2	0.200×26.0= 5.4
Age class 3	0.170×24.0= 4.08
Generation interval	2.238

The breeding goal in this research was assigned to increase body weight and mohair yield simultaneously. When all costs and profits of each trait were included as the economic weights in selection indices, the economic response to selection was fluctuated by different selection equations. The total economic gains ($) corresponded to selection indices (I1-I10) are illustrated in Figures 2. Based on Figure 2, the highest and lowest total economic gains were observed in the 3-trait selection index containing WW, W6, and mohair (I8) with 3.9 $and in the 2-trait selection index with BW and mohair yield (I1) with 0.54 $ respectively.

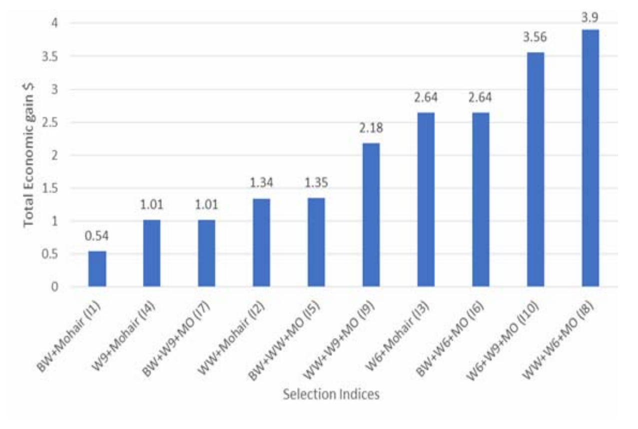

Figure 2 The total economic gain ($) of all 10 selection indices
BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight

According to previous studies, adding a trait with a higher weight to the index can lower the selection gain for the other trait and vice versa (Bett *et al.* 2007; Shokrollahi and Baneh, 2012; Ahmed *et al.* 2020; Getachew *et al.* 2022). However, the parallel selection of two traits is a kind of compromise between the selection gain for each trait. In the present study, the predicted economic weights for traits were such that body weights at 3 and 6 months were given a greater economic coefficient than mohair fleece weight. However, economic weights assigned to weight at 9 (1.5 $), and fleece weight (1.71 $) were close to each other, and the economic weight at birth was lower than that of mohair fleece. This pattern of trait importance in the designed selection indices highlights the significance of weight gain in the market age first and puts mohair production in the second degree of importance. However, in Turkey, mohair is known as the primary production of Angora Goat (Şenyüz, 2021).

The results of direct and indirect genetic gain for each trait in two-trait and three-trait selection indices are illustrated in Figures 3 and 4, respectively. Out of the 10 examined equations with the breeding objective of improving body weight and mohair yield simultaneously, 8 indices showed a positive genetic improvement in mohair (Figures 3 and 4). Among those, a two-trait selection index (I1) including birth weight and mohair yield showed the highest genetic gain for mohair production. Yet, all body weights suffered a negatively correlated response. So, this selection index cannot help achieving the defined breeding goal.

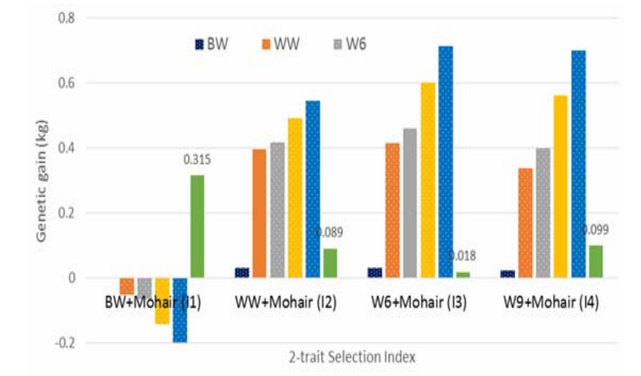

Figure 3 Direct and indirect genetic gains of traits in 4 two-trait selection indices (I1-I4) to improve both body weight and mohair yield. Solid bars represent direct responses and dotted bars represent indirect responses
BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight

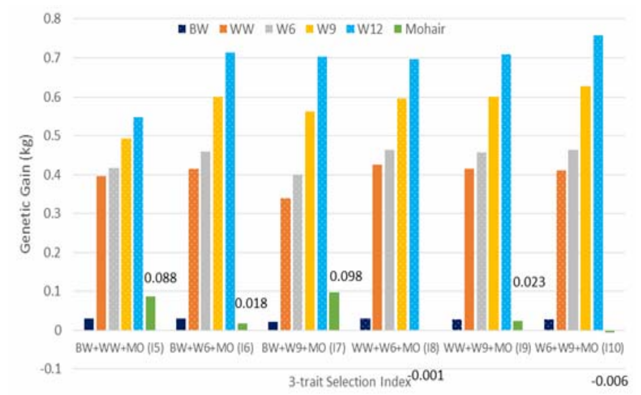

Figure 4 Direct and indirect genetic gains of traits in 6 three-trait selection indices (I5-I10) to improve both body weight and mohair yield. Solid bars represent direct responses and dotted bars represent indirect responses
BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight

Moreover, in only 4 selection indices (I2, I4, I5, and I7), the positive genetic gain (87-100 g) was predicted for mohair production alongside body weight improvement. Considering the determined breeding goal, the highest genetic gain in mohair with concurrent genetic gain in body weight was predicted in I4 and I7 selection indices. Accordingly, I4 and I7 are proposed as the most efficient selection indices for a simultaneous genetic improvement of body weight and mohair yield in Markhoz goat breeding. More specifically, the maximum direct genetic gains were estimated at 561 g for the weights at 9m and 99 g for mohair yield in the I4. Also, the maximum direct genetic gain was about 22 g for the birth weight, 562 g for the weight at 9m and 98 g for mohair yield in the I7 selection index.

As the findings showed, mohair production is almost genetically independent on the body weights at the beginning stage of the goat's life. Although this independence upon birth revealed a weak negative correlation at the age of 3 and 6 months and this negative correlation increases with increasing age until puberty. It can be concluded the negative correlation between body weight and mohair production is minimal in the early life of the Markhoz goat and is increasing as age increases. In this regard, a previous genetic analysis represented a non-negative correlation between early body weight and fleece weight in South African Angora goats which is consistent with the present findings (Snyman, 2020).

Mohair fleece weight and adult body weights were genetically unfavorably correlated and could lead to undesired genetic responses. Therefore, if two negatively correlated traits are considered for selection the genetic progress of one trait, which is accompanied by a reduction in its genetic variance, it can lead to a negative selection in another trait. Partially, its genetic variance increases at the Bulmer equilibrium (Snyman, 2012; Snyman, 2020). Thus, if mohair production is prioritized, it should either be included on its own or preferably together with the body weights in the early life of the Markhoz goat with a higher or equal economic weights in the selection index. Moreover, the small sample size (especially for mohair trait phenotypes) and a relatively high inbreeding frequency could be limiting factors.

Bulmer equilibrium parameters were estimated to scan how the genetic parameters of the studied population are changed through the selection strategies. As expected, the phenotypic variance and heritability decreased due to the Balmer effect after direct selection in each index. The greatest decrease was observed in the trait with the highest variance in the population. In this regard, the observed result was like the study by Van Grevenhofetal with the phenotypic records (Bulmer, 1971; Van Grevenhof *et al.* 2012). The phenotypic variance decrease in percentage for each included trait in all selection indices is shown in Figure 5. Accordingly, in direct selection, when the phenotypic variance of the trait is high, and the number of included traits is low the highest decrease in the phenotypic variance was occurred.

Figure 5 The percentage of phenotypic variance decrease of the included traits in 10 selection indices. Solid bars represent direct responses and dotted bars represent indirect responses
BW: body weights at birth; WW: weaning weight; W6: weight at 6 months; W9: weight at 9 months; W12: yearling weight and Mohair: mohair production weight

Therefore, by reducing the number of traits in the selection equation, the phenotypic variance, and finally genetic variance, and heritability of the corresponding traits were inevitably reduced. This trend has been also observed in the current study because the selection intensity of traits reduces by the decreased number of traits.

CONCLUSION

In the present study, the economic selection index method was used for a simultaneous selection to increase meat and mohair production traits. The breeding objective was to maximize the genetic gain of body weight and mohair yield in Markhoz goat. Ten different selection indices were examined and compared to finally designate the index which satisfied the breeding goal. Since the two traits of body weight and mohair fleece weight were somehow negatively correlated, some equations did not meet the breeding goal. It is recommended that in raising goats for meat production, goats should be reared until they are 9 months old, because after that the economic profit will be negative. Likewise, the selection index which included birth weight and mohair yield resulted in negatively correlated responses for body weights at all ages. However, in 7 equations (I2, I3, I4, I5, I6, I7, and I9) both body weight and fleece weight predicted to have positive genetic gains. An index of a 2-trait selection (I4) for replacement dams and sires in three age classes focusing on the improved meat and mohair yield were proposed for a simultaneous improvement of body weight and fleece weight in this Markhoz goat population. It is also possible to further improve the desired trait by increasing its coefficient in the selection equation.

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