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The Comparison of Four Economical Selection Indices for Improving the Performance of Kermani Sheep under Rural Production System

Research Article

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ABSTRACT

Developing effective selection programs for improving the performance of livestock requires taking the economical selection indices into account. The present study was performed for comparing four selection indices developed in Kermani sheep through simulated data. The relative importance of traits was determined based on the estimated economic values and consequently, the most beneficial traits were applied to develop the selection indices. The considered selection indices were different combinations of traits including ewe body weight (EBW), annual wool weight (AWW) and total weaning weight of lambs per exposed ewe (TWWEE). The first index included all three mentioned traits (EBW, AWW, and TWWEE). The second, third and fourth indices were included (AWW, TWWEE), (EBW, TWWEE) and (TWWEE), respectively. In general, the obtained results indicated that under all the developed selection indices the aggregate genotype, selection index and economic progress increased by increasing in the population size and decreasing in ram ratio, but resulted in reduced inbreeding average. In more cases, the aggregate genotype decreased by removing a trait from the index. The comparisons among indices indicated that the most suitable selection index for this breed under rural production system is the first index which included EBW, AWW, and TWWEE. This index had a maximum selection index average, aggregate genotype, and economic progress.

KEY WORDS computer simulation, genetic progress, inbreeding, Kermani sheep, selection criterion.

INTRODUCTION

Kermani is a meat and wool type, fat-tailed, medium-sized and white-wool sheep breed, indigenous to the southeastern areas of Iran and appropriately adapted to the unfavorable climatic conditions and pastures of low quantity and quality which is prevalent in the region (Mohammadabadi *et al.* 2017). The wool of Kermani sheep is fairly thick with a carpet grade. Mutton is the main source of red meat in Iran and now meat production from the sheep does not sufficient for increasing consumer demand.

The primary objective of a breeding program for any livestock species is to maximize the rate of genetic progress for economically important traits (Rashidi *et al.* 2008) such as body weight and reproductive performance. Increasing the profitability of any sheep production system is of great importance (Harris, 1970).

Hossein-Zadeh and Ardalan (2008) pointed out that meat production is one of the primary goals in sheep breeding of Iran. Ghiasi *et al.* (2016) reported that the number of lambs produced by each ewe constitutes the main part of income while milk production is of secondary importance and wool has no income or is little.

Falconer and Mackay (1996) recommended the application of selection indices for multi-trait selection in animal populations. Selection indices incorporate data on biological and also economic aspects of production simultaneously into a single value known as aggregate genotype (Parish *et al*. 2011; Paswan *et al*. 2016). Various breeding objectives and selection indices have been proposed in several livestock species such as indigenous chickens in Kenya (Okeno *et al*. 2012), Rayeni Cashmere goat (Kargar Borzi *et al*. 2017), wormsilk (Seidavi *et al*. 2008), buffalo (Agudelo-Gómez *et al*. 2016) and Aberdeen Angus cattle (Campos *et al*. 2014).

In Iran, under rural production systems, most sheep breeding enterprises may be unfavorably affected by the factors such as limited numbers of breeding males which increase the level of inbreeding in the flock.

In order to increase the genetic progress and decrease the rate of inbreeding, the establishment of a suitable selection index considering factors such as flock size, ram ratio and traits of interest is necessary. As Kermani sheep breed mainly reared under the rural system, there is no information on the suitable selection indices for improving the performance of flocks under such systems. Up to our knowledge, there is no information on such selection indices. Therefore, the present study was performed for comparing different selection indices in Kermani sheep under rural production systems.

MATERIALS AND METHODS

Breeding objective and selection criteria

Different areas of the Kerman province, which located in the south-eastern part of Iran, were chosen for gathering the required information. Five farmers were considered finally to take part in the present investigation. All farmers expected to increase their economic profit from their sheep flocks through higher meat and wool output and also reduced costs. Therefore, higher reproduction rate, higher growth rate and higher wool weight of the sheep are of primary interest. To select animals for the increased quantity of meat and wool produced, ewe body weight, annual wool weight and total weaning weights of lambs per exposed ewe, were used as selection criteria. The breeding objectives of rural production systems in Kermani sheep were acquired from economic analysis and the conversation with flock holders. So, breeding goals (meat production and wool production) and selection criteria (body weight (kg), total weaning weight for each exposed ewe (kg) and wool production (kg)) for Kermani sheep were considered.

Structure of (co)variance matrix

The phenotypic and genetic (co)variance matrix (Table 1) was derived from the data of experimental breeding station of Kermani sheep, located in Shahrbabk, southeast of Iran, which collected over a period of 18 years (1993-2011). (co)variance components for the traits were estimated by the Average Information Restricted Maximum Likelihood (AI-REML) method fitting an animal model. For this purpose, the WOMBAT computer program was used (Meyer, 2006). The required information which was accessible from those records also was reported in some research (Bahreini Behzadi *et al*. 2007; Mokhtari *et al*. 2008; Mokhtari *et al*. 2010).

Economic analysis

Microsoft excel spreadsheets were used to estimate productive and reproductive efficiency as well as of the costs and incomes. The systems, production costs and revenues, and profit equation were estimated as explained by Kosgey *et al*. (2003). In the present study, a deterministic static model was used for calculating the economic values (EVs) of decisive traits of Kermani sheep. The total annual profit of the flock was derived as the difference between costs and revenues of the system.

The average prices in 2011 were used and all costs and prices were expressed in Dollar. The productive and time units were the ewe and year, respectively. The inputs for the production system were feed, management, and fixed costs. The outputs were revenues from the sale of cull ewes and rams, excess lambs and wool. The input parameters were taken from the five Kermani sheep flocks with a total size of 635 heads. The economic value of each trait (V_i) was obtained by Eq. (1)

$$V_i = P_i - P \qquad (1)$$

Where:
P and P_i: profits before an increase and after increase of the trait by 1%, keeping all other traits at their mean value simultaneously (Lobo *et al*. 2011).

Data simulation and flock structure

To determine the appropriate selection index for Kermani sheep, the productive population was simulated. For this purpose, the base population was randomly established based on genetic and phenotypic (co)variance matrices (Table 1) of Kermani sheep and the means of the studied flocks (Table 2) by applying the Visual Basic 6.0 programming language. The assumptions and the statistical distribution of the simulated parameters are presented in Table 3.

After simulating the phenotypic records of the base population, for obtaining the phenotypic records of the offspring random mating was done between top adult rams and ewes (the best parents) as follows:

$$y_0 = \mu + 0.5g_b + 0.5g_d + m + e$$

$m = 0.5 (2-F_b-F_d) 0.5ZL_G$

Where:

y_0: vector of offspring phenotypic records.

μ: vector of mean of the trait considered.

g_b and g_d: vectors of breeding values for rams and ewes respectively.

m: vector of Mendelian sampling.

e: vector of residuals.

Z: vector of random numbers normally distributed with a mean of zero and variance equal to one.

L_G: lower triangular matrix obtained from Chalsky analysis G.

F_b and F_d: inbreeding coefficients for rams and ewes, respectively.

Top adult rams and ewes were selected based on economic selection index. To choose the best parents, the selection index for each animal was established.

Flock size, ram ratio, numbers of generations, numbers of traits, litter size, percentage of ram and ewe in the flock, longevity of rams and ewes in the flock, age of the animal at maturity and mortality rate were defined similarly to the considered Kermani sheep flocks (Table 2).

The overlap between generations was considered. Selection indices were derived by changing the ram ratio from 2 to 8 percent.

Developing the selection indices

Four selection indices with different herd size and ram ratio were proposed (I_1–I_4) to compare genetic and economic gain and inbreeding rate with computer simulation after selected 10 years. The traits included in indices were: ewe body weight (EBW), annual wool weight (AWW) and total weaning weight of lambs per exposed ewe (TWWEE). The first index (I_1) was considered as a full selection index that included all the considered traits. To decrease the cost of trait measurement, other selection indices were proposed to detect the appropriate selection index. The traits contained in each index were as follows: EBW, AWW, and TWWEE (I_1); AWW and TWWEE (I_2); EBW and TWWEE (I_3) and TWWEE (I_4).

Economic gain under each index was defined as:

$$E = \sum(EVi \times BVi) \quad (2)$$

Where:

EVi: absolute economic value of the ith trait involved in the index.

BVi: breeding value for the ith trait included in the index.

Aggregate genotype (H) was defined as:

$$H = \sum vi \times gi \quad (3)$$

Where:

vi: relative economic value of the ith trait in the aggregate genotype.

gi: breeding value of the ith trait in the aggregate genotype.

RESULTS AND DISCUSSION

Economic analysis

The absolute and relative economic values of studied traits are shown in Table 1. Relative economic values of EBW, AWW, and TWWEE traits were - 1.95, 1.00 and 14.48, respectively. The calculated economic values, except EBW, were positive. Positive economic value for a trait indicated that genetic progress in that trait would positively influence on the profitability of the breeding system. Negative economic values for body weight traits were also reported in literature (Bett *et al.* 2011; Kargar Borzi *et al.* 2017). Economic increase comes from higher meat and wool output as well as reduction of costs in sheep flocks. Hence, higher reproduction and growth rate and wool weight are economically important. The economic value for total weaning weight of lambs per exposed ewe was larger than the other traits (Table 1), implied that TWWEE has higher influence on the costs of production system than other studied traits.

The comparison of selection indices

The values of inbreeding under the considered selection indices (I_1 to I_4), different flock size and ram ratio are shown in Table 4. The obtained results showed that inbreeding was reduced by increased flock size and ram ratio, accordingly. The lowest value of inbreeding was obtained under I_4 which included TWWEE in flock size of 300 and ram ratio of 0.08. Kosgey *et al.* (2003) reported that the increase in flock size would be associated with decreased genetic gain and inbreeding. Therefore, for preventing the increase of inbreeding in small-sized flocks, the ram ratio should be increased (Kosgey *et al.* 2003).

As shown in Table 4, the maximum value for selection index (183.54) was obtained under the first index, I_1, with flock size of 200 and ram ration of 0.02 while the minimum one (135.10) was obtained under I_2, flock size of 100 and ram ratio of 0.08. Inbreeding ranged from 0.052 (under I_4, flock size of 300 and ram ratio of 0.08) to 0.288 (under I_1, flock size of 100 and ram ratio of 0.02).

The values of aggregate genotype and economic gain under different flock size and ram ratio across four selection indices (I_1 to I_4) are shown in Table 5.

Table 1 Estimates of mean, economic values and structure of (co)variance matrix for Kermani sheep[1]

Trait (kg)	Mean (SD)	Absolute economic values ($)	Relative economic values	EBW	AWW	TWWEE	Indices			
							I1	I2	I3	I4
EBW	38 (5.62)	- 4.5	-1.95	1.25 (7.05)	0.11	1.09	✓	✓	✓	✓
AWW	0.65 (0.10)	2.3	1	0.73	0.08 (0.46)	0.04	✓	✓	✓	✓
TWWEE	18 (2.31)	33.30	14.48	3.89	1.34	2.26 (7.22)	✓	✓	✓	✓

[1] Genetic variance in diagonal and residual variance in diagonal (in parentheses); residual (below diagonal) and genetic (above diagonal) covariances.
EBW: ewe body weight; AWW: annual wool weight and TWWEE: total weaning weight for each exposed ewe.
SD: standard deviation.

Table 2 Overview of the assumed values for the input variables of the study

Variables	Value	Variables	Value
Flock structure		Birth weight (kg)	3.8
Number of the ewe in flocks	600	Weaning weight (kg)	20
Number of ram in flocks	35	Mature weight of rams (kg)	49
Conception rate (%)	93	Mature weight of ewes (kg)	38
Number of lamb in year	1.38	Weight of lambs yearling (kg)	23
Number of lamb per birth	1.1	Wool weight (kg)	0.65
Ewe survival (%)	94	Management variables	
Replacement survival (%)	93	Weaning age of lambs (months)	4
Pre-weaning survival (%)	81	Age of selection replacement (months)	8
Post-weaning survival (%)	92	Age at first mating (months)	18
Replacement rate (%)	29	Age at Mature weight (months)	18
Culling rate of ewes (%)	21	Age at culling of the ewe (year)	6
Culling rate of rams (%)	1.7	Age at culling of rams (year)	4
Production variables		The proportion of rams in flock (%)	5

Table 3 The assumptions and statistical distribution of the simulated parameters

$y = \mu + g + e$	$y = N(\mu, \sigma^2)$	$\sigma^2 = G + R$
$g = LG' Z'_1$	$g \sim N(0, G)$	$G = L_G L'_G$
$e = LRZ'_2$	$e \sim N(0, R)$	$R = L_R L'_R$

y: vector of phenotypic records; μ: vector of mean of traits; g: vectors of additive genetic value for traits; e: vector of residuals; G: matrix of additive genetic (co)variance; R: residuals (co)variance; LG and LR: lower triangular matrix obtained from Chalsky analysis G and R respectively and Z_1 and Z_2: vectors of random numbers normally distributed with a mean of zero and variance equal to one.

Table 4 The values of inbreeding and selection index under different flock size and ram ratios of Kermani sheep

Flock size	Index[¥]	Ram ratio							
		0.02		0.04		0.06		0.08	
		Inbreeding	Selection index	Inbreeding	Selection index	Inbreeding	Selection index	Inbreeding	Selection index
100	I1	0.288	154.36	0.197	152.12	0.167	146.92	0.121	136.97
	I2	0.258	152.41	0.189	147.11	0.146	141.30	0.131	135.10
	I3	0.262	152.6	0.188	144.62	0.146	138.11	0.129	135.54
	I4	0.275	161.28	0.179	155.11	0.171	150.68	0.137	143.45
200	I1	0.191	173.51	0.127	153.83	0.109	146.16	0.075	140.02
	I2	0.205	161.25	0.119	150.33	0.090	150.42	0.067	141.21
	I3	0.207	171.25	0.131	149.51	0.097	146.96	0.077	140.54
	I4	0.188	168.27	0.123	160.61	0.089	159.75	0.076	154.16
300	I1	0.150	183.54	0.099	160.60	0.066	149.33	0.054	141.46
	I2	0.166	164.12	0.096	163.72	0.069	154.09	0.062	153.09
	I3	0.159	175.01	0.098	172.64	0.070	160.12	0.066	145.43
	I4	0.133	174.20	0.098	170.62	0.064	161.19	0.052	159.16

I1: included ewe body weight (EBW), annual wool weight (AWW), and total weaning weight of lambs per exposed ewe (TWWEE); I2: included annual wool weight (AWW) and total weaning weight of lambs per exposed ewe (TWWEE); I3: included ewe body weight (EBW) and total weaning weight of lambs per exposed ewe (TWWEE); I4: included total weaning weight of lambs per exposed ewe (TWWEE).

Under the first selection index (I$_1$), the highest amount of aggregate genotype value (183.64) and economic gain (123.65 $) was obtained. By considering the second selection index (I$_2$), aggregate genotype value and economic gain were varied between 136.10 to 169.12 and 93.79 to 115.57 $, respectively.

Under the third selection index (I$_3$), a minimum amount of aggregate genotype value (136.04), and economic gain (86.39 $) was obtained. Under the fourth selection index (I$_4$), aggregate genotype value and economic gain were varied between 145.45 to 175.20 and 79.78 to 114.73 $, respectively. Under all developed selection indices, in flock size of 300 and ram ratio of 0.02 the highest amount of aggregate genotype value and economic gain was achieved. A reduction in ram percent will precipitate genetic progress because of the high selection intensity (Falconer and Mackay, 1996).

Economic values were positive for AWW and TWWEE but not for EBW, implying that by increasing body weight of ewes, the profit would be reduced. Obtained negative economic values for ewe body weight were in agreement with the result obtained by Bett *et al*. (2011). Also, Conington *et al*. (2004) reported a negative economic value for mature body weight. The highest economic value was obtained for TWWEE.

Likewise, Gallivan (1996) pointed out that reproductive traits have high economic value in Canadian sheep. The main influencing factors to be considered in genetic selection strategies are the accuracy of selection, selection intensity, effective population size and mating system (Falconer and Mackay, 1996).

Therefore, optimum response to selection may be achieved by maximizing the accuracy of selection, selection intensity and additive genetic variance or effective population size (Falconer and Mackay, 1996). But, all of these factors cannot be maximized, with limited resources. For example, increasing selection intensity decreases effective population size, which consequently resulted in a reduction in response to selection.

Likewise, increasing the accuracy of selection by use of selection indices also reduces effective population sizes, which lead to a quicker increase in the rate of inbreeding (Quinton and Smith, 1995). Inbreeding rates are speed up in livestock, and inbreeding causes economic losses through depression in production, growth, health, and fertility (Weigel, 2001). To increase genetic progress and limit the rate of inbreeding, establishment of appropriate selection index based on different herd size and ram ratio were the purpose of this research. The obtained results (Table 4) showed that the mean of inbreeding during 10 generations of selection was reduced with an increase in flock size and ram ratio. The increase in inbreeding negatively influences on genetic variance and decrease the genetic gain, accordingly (Falconer and Mackay, 1996).

Therefore, for reducing the mean of inbreeding, large flock size and the adequate number of rams for mating are required. It is obvious that adequate number of rams for mating can reduce effectively the rate of inbreeding over generations with a minimal decrease of selection response. Therefore, the results of the present study will guide Kermani sheep breeders focus on a scheme to decide the starting numbers of basis animals to create a breeding herd.

Table 5 The values of aggregate genotype and economic gain ($) under different flock size and ram ratios of Kermani sheep

Flock size	Index	Ram ratio							
		0.02		0.04		0.06		0.08	
		Aggregate genotype	Economic gain ($)	Aggregate genotype	Economic gain ($)	Aggregate genotype	Economic gain ($)	Aggregate genotype	Economic gain ($)
100	I$_1$	155.36	114.171	152.32	111.397	147.92	99.495	137.97	94.270
	I$_2$	152.42	102.584	147.1	101.581	141.80	97.482	136.10	93.787
	I$_3$	153.6	105.794	144.68	98.7177	138.41	94.011	136.04	86.390
	I$_4$	163.28	99.114	157.11	88.548	150.88	82.614	145.45	79.775
200	I$_1$	174.51	121.619	154.83	115.464	148.18	100.688	140.02	97.367
	I$_2$	163.25	104.511	151.33	103.32	150.46	103.140	141.51	102.409
	I$_3$	171.45	116.183	149.56	102.231	147.96	101.362	140.74	98.825
	I$_4$	168.27	112.859	160.64	111.221	159.75	102.243	154.16	94.494
300	I$_1$	183.64	123.652	160.70	117.639	149.33	101.070	143.46	98.606
	I$_2$	169.12	115.571	163.75	108.857	155.09	106.473	153.29	105.306
	I$_3$	175.21	118.169	172.68	117.577	160.18	108.453	146.43	99.642
	I$_4$	175.20	114.734	170.92	113.105	163.19	105.628	159.56	102.386

I$_1$: included ewe body weight (EBW), annual wool weight (AWW), and total weaning weight of lambs per exposed ewe (TWWEE); I$_2$: included annual wool weight (AWW) and total weaning weight of lambs per exposed ewe (TWWEE); I3: included ewe body weight (EBW) and total weaning weight of lambs per exposed ewe (TWWEE); I$_4$: included total weaning weight of lambs per exposed ewe (TWWEE).

To prevent excessive inbreeding in the flock, small-sized flocks may be combined. The increase of flock size will cause a reduction of inbreeding, and increase of genetic and economic gain, accordingly. Then, decrease of ram up to 2 % and increase of flock size up to 300 may be suggested as the most suitable breeding program for Kermani sheep under extensive production system.

The annual response to selection applying a multi-trait selection index will be smaller in each component trait than the selection accomplished for that trait individually. However, it is important to evaluate all traits with economic value, to improve genetic progress and the greatest rate of change in overall economic merit. Selection for reproductive traits should be based on a criterion that is highly similar to the breeding goals; for example, if the selection is based on the number of lambs, the frequency of genes affecting the total weight of the lamb is not sufficiently affected.

Snyman *et al*. (1996) indicated that the selection for the number of lambs born per ewe is only significant for the number of lambs and will not increase the weight of lambs; while the selection for total weaning weight per ewe will also increase individual weight gain of lambs. Therefore, traits that were considered in the full selection index included EBW, AWW, and TWWEE. Response to selection increased with an increase in herd size. However, with an increase in ram ratio, response to selection decreased (Tables 4 and 5). The highest genetic and economic responses were obtained under the first index (I_1). Under the second selection index (I_2), the least genetic and economic responses to selection were obtained. Among the developed selection indices in the present study, the first one, which included all the three considered traits into account, may be taken as the best one for flock holders of Kermani sheep. Anyhow, if meat quantity to be the first interest of the flock holders of Kermani sheep, the third index (I_3) which combines ewe body weight and total weaning weight of lambs per exposed ewe may be an appropriate alternative.

CONCLUSION

Results of the present study indicated that, for the genetic improvement of Kermani sheep populations, Index 1, with all traits including (ewe body weight, annual wool weight and total weaning weight for each exposed ewe), may be used appropriately. The choice and use of the index depending on the definition of objectives. The results of the study can be used to design local sheep breeding programs in Iran, and in other countries in low-input production systems with low technological progress, such that those found in the tropics.

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