Inbreeding Effects on Reproductive Traits of Mehraban Sheep

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Summary

Inbreeding effects on reproductive traits were measured in Mehraban sheep using 10275 lambing records (1994-2011) from the Breeding Station of Mehraban sheep (Hamedan Province, Iran). The reproductive traits were litter size at birth per ewe lambing (LSB), litter size at weaning per ewe lambing (LSW), total litter weight at birth per ewe lambing (TLWB), total litter weight at weaning per ewe lambing (TLWW), litter mean weight per lamb born (LMWLB) and litter mean weight of lambs at weaning (LMWLW). Inbreeding depression was estimated by the Reg procedure of SAS. Inbreeding of all animals was calculated by INBUPGF90 program. All animals were grouped into two classes according to their inbreeding coefficients: the first class included non-inbred animals (F=0); and the second class included inbred animals (F>0). In different inbreeding classes, the LSW and LMWLB showed significant differences ($P<0.05$), but there were no significant differences in LSB, LMWLW, TLWB and TLWW traits. The regression coefficients of LSB, LSW, LMWLB, LMWLW and TLWW on lamb inbreeding were estimated to be 0.13±0.01, 0.36±0.02, -7.79±0.54, 38.01±4.80 and 108.89±14.18 ($P<0.01$), respectively. The results showed that effect of inbreeding on reproductive traits in this breed was very pronounced in the flock. Both positive and negative inbreeding effects were found in the current study. However, planned matings would avoid accumulation of inbreeding and appearance of its deleterious effects.

Key words

fat-tailed sheep, inbreeding depression, mating program, reproduction traits

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Introduction

The objective of breeding programs is to maximize the rate of genetic progress for economically important traits in livestock species. The reproductive traits are undoubtedly the most important traits in all systems of sheep production (Amou et al., 2013, Matika et al., 2003). The reproductive performance is the most important factor affecting animal production and litter size at birth, due to its high correlation with the number of lambs weaned, is considered as one of the most important components of this function (Menedez Buxadera et al., 2004). Ewe productivity is a key objective in sheep breeding and could be improved by increasing the number of lambs weaned and lambs weaned weight per ewe within a special year (Duguma et al., 2002). In any sheep production system, lamb production is the major source of income (Ekiz et al., 2005). Although low heritability of litter size is known as a limiting factor for genetic improvement of reproductive performance in domestic species, but genetic changes of litter size were reported in many sheep populations (Eteqadi et al., 2015; Amou et al., 2013; Ghavi Hossein-Zadeh, 2010a; Vatankhah et al., 2008).

Mating between relative individuals in a closed population leads to accumulation of inbreeding in later generations (Falconer and Mackay, 1996). Inbreeding could damage the reproduction, growth, production, health and survival traits. Homozygosity rate increases by inbreeding increases, which decreases performance of traits related to competence and production. The reproductive traits include traits related to animal competence that decreases performance with the increase of inbreeding (Pedrosa et al., 2010; Szwaczkowski et al., 2003).

One of the important Iranian sheep breeds is Mehraban. The origin of this breed is in Hamedan, the western province of Iran, and it is adapted to harsh climate and rocky environments in the western regions of the Iran. The Mehraban is a fat-tailed carpet wool sheep with light brown, cream or grey color, dark face and neck and primarily used for meat production (Yavarifard et al., 2015; Aghaali Gamasaee, 2010). There is no published research on the effect of inbreeding on reproductive traits in Mehraban sheep. Therefore, the objective of present study was to study effect of inbreeding on reproductive traits in Mehraban sheep.

Materials and methods

Data

Data used in this research were reproductive performance traits of Mehraban ewes collected at the Breeding Station of Mehraban sheep, located in Kabudarahang city, Hamedan province, Iran during 18-year period from 1994 to 2011. In this province, the predominant sheep breed is Mehraban, numbering approximately 2.1 million heads. They are well adapted to the cold climate. Meat of this breed is the main source of income for producers. Data included 10257 records on reproductive performances of 5813 lambs from 69 sires and 603 dams. Ewes were exposed to the rams at about 18 months of age. Matings were controlled and each mating groups including 10–15 ewes were set aside to a ram. Ewes were kept in the flock up to seven years of age. Ewes usually give births to lambs three times every two years. Rams were kept until a male offspring was available for replacement. The lambs were weaned at around 90 days of age. Flocks were grazed during the daytime and housed at night. The lambs were kept indoors and fed manually during the winter (Yavarifard et al., 2014). Defective and doubtful data, including outliers and out of range records, were identified after data screening and deleted from the analysis. Descriptive statistics of reproduction traits are shown in Table 1. Also, all the animals were grouped into two classes according to the inbreeding coefficients obtained by their pedigree: the first class included non-inbred animals (F=0%); and the second class included inbred animals (F>0).

Studied traits

The reproductive traits analyzed can be classified as basic and composite traits. Basic traits were litter size at birth (LSB), litter size at weaning (LSW), litter mean weight per lamb born (LMWLB), and litter mean weight per lamb weaned (LMWLW). LSB was the number of lambs born alive per ewe lambing (1, 2) and LSW was the number of lambs weaned per ewe lambing (0, 1, 2). LMWLB and LMWLW were the average weights of lambs from the same parity at birth and weaning, respectively. Composite traits were total litter weight at birth per ewe lambing (TLWB) and total litter weight at weaning per ewe lambing (TLWW). TLWB refers to the sum of the birth weights of all lambs born per ewe lambed and TLWW refers to the sum of the weights of all lambs weaned per ewe lambed.

Statistical analyses

Descriptive statistics of reproduction traits were identified by preliminary analysis using the MEANS procedure of SAS (SAS Institute, 2003). Inbreeding depression was estimated by the Reg procedure of SAS as the regression of reproduction traits on the individual inbreeding coefficients. Inbreeding of all animals was calculated by INBUPGF90 program (Aguilar and Misztal, 2012).

Table 1. Descriptive statistics of reproduction traits in Mehraban sheep

Traits	LSB	LSW	LMWLB(kg)	LMWLW(kg)	TLWB(kg)	TLWW(kg)
N	10275	10275	10275	10275	10275	10275
Mean (kg)	1.12	0.76	3.67	22.07	4.35	28.04
SD (kg)	0.33	0.72	0.76	4.24	1.28	12.52
CV (%)	29.46	94.73	20.74	19.21	29.33	44.65
min	1	0	1.4	9	1.4	9
max	3	3	6	35.70	15	105

LSB: litter size at birth, LSW: litter size at weaning, LMWLB: litter mean weight per lamb born, LMWLW: litter mean weight per lamb weaned, TLWB: total litter weight at birth, TLWW: total litter weight at weaning.

This program calculates inbreeding coefficients using a recursive algorithm assuming non-zero inbreeding for unknown parents and was used for calculating regular inbreeding coefficients for individuals. Fixed factors affecting on reproductive traits were identified using the GLM procedure of SAS (SAS Institute, 2003). The fixed effects included in the statistical models were flock-year-season, lamb sex in two classes (male and female), dam age at lambing in six classes (2-7 years old) and interaction between them for all traits as well as effect of birth type in three classes (single, twin and triplet) for LMWLB, LMWLW, TLWB and TLWW. Lamb age at weaning (in days) was fitted as a covariate for LMWLW and TLWW. Inbreeding coefficient of animals was fitted in the statistical model of analysis for all reproductive traits with two classes (F=0% and F>0). Differences between least squares means of reproductive traits in different inbreeding classes were tested using Tukey test.

Results and discussion

The summary statistics for reproduction traits in different inbreeding classes of animals is shown in Table 2. The LSB of non-inbred animals had not significant difference with that in inbred animals. The LSW within second class of inbreeding was higher than that of non-inbred lambs (P<0.05). Also, there was significant difference between two classes of inbreeding in LMWLB and animals within first class of inbreeding had greater mean of the trait than other group (P<0.05). In addition, there were no significant differences between inbreeding classes for LMWLW, TLWB and TLWW. These results are almost similar to the reports of other researchers (Rzewuska et al., 2005; Ercanbrack and Knight, 1991).

Generally, inbreeding is associated with deterioration in growth and reproductive traits in animal and level of inbreeding may be an important factor for such effects to appear (Wocac, 2003; Ghavi Hossin-Zadeh, 2013). The inbreeding level estimates are strongly determined by the two main factors: depth and completeness of pedigree and selection intensity. A high inbreeding level is observed for populations rebuilt from small number of founders, which can be due to a large number of animals with one or two unknown parents in the pedigree and incompleteness of pedigree. Therefore, this resulted in the greater numbers of unknown common ancestors that was led to lower estimates of the inbreeding coefficient is the next generation (Barczak et al., 2009; Yavarifard et al., 2014). Even with a rather small proportion of unknown pedigrees (10%), inbreeding is strongly underestimated.

Male lambs showed no significant differences in their LSB, LMWLB, LMWLW and TLWB irrespective of the inbreeding coefficient (Table 3). The LSW of animals within first class of inbreeding (F=0) was higher than inbred lambs (P<0.05). Also, the TLWW of animals within first class of inbreeding was significantly (P<0.05) lower than those of lambs belonging to the second class. Female lambs showed no significant differences in their LSB, LMWLB, LMWLW, TLWB and TLWW irrespective of the inbreeding coefficient. Also, the LSW of animals within first class of inbreeding (non-inbred lambs) was significantly (P<0.05) lower than those of lambs belonging to the second class (inbred animals). Similar to the current results, Eteghadi et al. (2015) reported no significant difference between inbreeding classes in the LMWLW of male lambs, in the LMWLB of male lambs and in the LMWLW of female lambs.

Table 2. Distribution and comparison of records for reproductive traits in different inbreeding classes of Mehraban sheep

Class of inbreeding	Traits											
	LSB		LSW		LMWLB(kg)		LMWLW(kg)		TLWB(kg)		TLWW(kg)	
	Mean±SE	N	Mean±SE	N	Mean±SE	N	Mean±SE	N	Mean±SE	N	Mean±SE	N
F=0	1.12^{a}±0.01	1503	0.44^{b}±0.01	580	3.88^{a}±0.001	1503	21.89^{a}±0.12	580	4.28^{a}±0.03	1503	25.31^{a}±0.36	580
F>0	1.25^{a}±0.01	8772	0.81^{a}±0.01	5590	3.65^{b}±0.001	8772	22.09^{a}±0.28	5590	4.36^{a}±0.01	8772	28.32^{a}±0.18	5590

LSB: litter size at birth, LSW: litter size at weaning, LMWLB: litter mean weight per lamb born, LMWLW: litter mean weight per lamb weaned, TLWB: total litter weight at birth, TLWW: total litter weight at weaning. F: inbreeding, SE: standard error; ^{a,b}Means within each column that do not have a common superscript are significantly different (P<0.05).

Table 3. Distribution and comparison of records for reproductive traits in different inbreeding classes grouped by the sex of lamb in Mehraban sheep

Lamb sex	Inbreeding class	N	LSB Mean±SE	LSW Mean±SE	LMWLB(kg) Mean±SE	LMWLW(kg) Mean±SE	TLWB(kg) Mean±SE	TLWW(kg) Mean±SE
	F=0	713	1.12^{a}±0.32	0.46^{b}±0.60	3.96^{a}±0.51	22.02^{a}±4.70	4.28^{a}±1.03	25.30^{b}±9.95
Male	F>0	4275	1.26^{a}±0.48	0.85^{a}±0.73	3.77^{a}±0.82	22.26^{a}±4.17	4.36^{a}±1.33	28.88^{a}±12.99
	F=0	790	1.12^{a}±0.33	0.43^{b}±0.60	3.81^{a}±0.50	21.76^{a}±4.51	4.21^{a}±1.04	25.31^{a}±10.23
Female	F>0	4497	1.22^{a}±0.46	0.78^{a}±0.73	3.54^{a}±0.76	21.93^{a}±4.23	4.19^{a}±1.27	27.76^{a}±12.41

LSB: litter size at birth, LSW: litter size at weaning, LMWLB: litter mean weight per lamb born, LMWLW: litter mean weight per lamb weaned, TLWB: total litter weight at birth, TLWW: total litter weight at weaning. F: inbreeding, SE: standard error; ^{a,b}Means within each column that do not have a common superscript are significantly different (P<0.05).

Table 4. Distribution and comparison of records for reproductive traits in different inbreeding classes grouped by the type of birth in Mehraban sheep

Lamb sex	Inbreeding class	N	Traits LSB Mean±SE	LMWLB(kg) Mean±SE	TLWB(kg) Mean±SE	N	Traits LSW Mean±SE	LMWLW(kg) Mean±SE	TLWW(kg) Mean±SE
	F=0	1322	1ᵃ±0.00	3.96ᵃ±0.47	3.96ᵃ±0.47	493	1ᵃ±0.00	21.73ᵃ±4.63	21.73ᵃ±4.63
Single	F>0	6771	1ᵃ±0.00	3.87ᵃ±0.67	3.87ᵃ±0.67	4166	1ᵃ±0.00	21.97ᵃ±4.33	21.97ᵃ±4.33
	F=0	181	2ᵃ±0.00	3.33ᵃ±0.46	6.67ᵃ±0.92	87	2ᵃ±0.00	22.78ᵃ±4.33	45.56ᵃ±8.67
Twin	0<F<0.05	1840	2ᵃ±0.00	2.95ᵇ±0.74	5.89ᵇ±1.48	1284	2ᵃ±0.00	22.38ᵃ±3.78	44.76ᵃ±7.55

LSB: litter size at birth, LSW: litter size at weaning, LMWLB: litter mean weight per lamb born, LMWLW: litter mean weight per lamb weaned, TLWB: total litter weight at birth, TLWW: total litter weight at weaning. F: inbreeding, SE: standard error; [a,b]Means within each column that do not have a common superscript are significantly different (*P*<0.05).

Table 5. Regression coefficients (±SE) of reproductive traits on inbreeding of lambs for a change of 1 % in inbreeding

	LSB	LSW	LMWLB (g)	LMWLW (g)	TLWB (g)	TLWW (g)
Single	-	-	-3.74**±0.47	40.81**±5.23	-3.74**±0.47	40.81**±5.23
Twin	-	-	-14.89**±1.74	-0.97±13.62	-29.79**±3.47	-1.95±27.24
Female	0.15**±0.03	0.38**±0.03	-6.52**±0.66	23.95**±6.05	-0.68±1.14	55.65**±17.41
Male	0.11**±0.02	0.34**±0.03	-9.73**±0.87	63.41**±7.90	4.63**±1.46	204.73**±23.91
Total	0.13**±0.01	0.36**±0.02	-7.79**±0.54	38.01**±4.80	1.47±0.91	108.89**±14.18

LSB: litter size at birth, LSW: litter size at weaning, LMWLB: litter mean weight per lamb born, LMWLW: litter mean weight per lamb weaned, TLWB: total litter weight at birth, TLWW: total litter weight at weaning. F: inbreeding, SE: standard error; ***P<0.01*

Single-born lambs showed no significant differences in all traits irrespective of the inbreeding coefficient (Table 4). In addition, twin-born lambs showed no significant differences in their LSB, LSW, LMWLW and TLWW. Although single-born lambs showed no significant differences in their LMWLB and TLWB, twin-born lambs showed significant differences between two classes of inbreeding on LMWLB and TLWB, and animals within first class of inbreeding had greater mean of the trait than other group (*P*<0.05). Similar to the current results, Eteghadi et al. (2015) reported no significant difference in the LSB and LSW of single lambs and the LSB of twin lambs.

Table 5 shows the regression coefficients of reproduction traits on inbreeding of lambs for a change of 1% in inbreeding. The regression coefficients of all traits except TLWB on inbreeding of all lambs were significantly positive. The regression coefficients of LSB, LSW, LMWLB, LMWLW and TLWW on lamb inbreeding were estimated to be 0.13±0.01, 0.36±0.02, -7.79±0.54, 38.01±4.80 and 108.89±14.18 (*P*<0.01), respectively, then LMWLB decreased by 7.79 g due to 1% increase in inbreeding and LSB, LSW, LMWLW and TLWW increased, respectively, by 0.13 g, 0.36 g, 38.01 g and 108.89 g due to 1% increase in inbreeding. The regression coefficient of TLWB on inbreeding of lambs for change of 1% in inbreeding was positive and not significant. Considering the birth type, the regression coefficient of LMWLW and TLWW on inbreeding of single-born lambs was significantly positive (40.81 ±5.23, *P*<0.01). Therefore, LMWLW and TLWW of singles increased 40.81 g due to 1% increase in inbreeding. The regression coefficients of LMWLB and TLWB in single-born were significant and their corresponding value was -3.74±0.47 (*P*<0.01). In addition, the regression coefficients of LMWLB and TLWB on inbreeding of twin-born lambs were significantly negative (-14.89±1.74 and -29.79±3.47, (*P*<0.01), respectively). Also, considering the sex of lambs, the LSB, LSW, LMWLW, TLWB and TLWW of male lambs increased by 0.11 g, 0.34 g, 63.41 g, 4.63 g and 204.73 g, respectively (*P*<0.01), and LMWLB of male lambs decreased by 9.73 g due to 1% increase in inbreeding (*P*<0.01). On the other hand, LSB, LSW, LMWLW and TLWW of female lambs increased 0.15 g, 0.38 g, 23.95 g and 55.65 g, respectively (*P*<0.01), and the LMWLB of female lambs decreased by 6.52 g due to 1% increase in inbreeding (*P*<0.01).

In the current study effect of inbreeding on traits was significant. Many authors reported negative effects of inbreeding on reproduction traits. In the study reported by Ercanbark and Knight (1991) inbreeding effect was breed-dependent, not significant in Rambuillet and Targhee, but significant in Columbia sheep. Lamberson et al. (1982) and Wiener et al. (1992) in Hampshire sheep and Eteghadi et al. (2015) in Guilan sheep reported decrease in reproduction traits due to 1% increase in inbreeding. Rzewuska et al. (2005) did not support negative effects of inbreeding on fertility and other reproduction traits and reported that ovulation rate was not related to inbreeding level, as the trait is determined by the single gene of major effect. Sajjad Khan et al. (2007) reported both positive and negative inbreeding effects on reproduction traits. Lamberson and Thomas (1984) reviewed the effects of inbreeding on ewe and lamb performance as observed, and found that the regression of the individual's performance on level of the individual's inbreeding generally indicated that inbreeding was detrimental to performance, which is almost in agreement with the results of this study.

When studying real populations, an important property is the sensitivity to incomplete pedigree information. In large domestic animals, the pedigree information is limited, incomplete, and variable across animals. However, low inbreeding depression does not originate from missing pedigree records, rather, it is due to real lack of effect of these traits in the breed (Dorostkar et al., 2012). Inbreeding is generally associated with deterioration in growth in reproductive traits in small ruminants and level of inbreeding may be an important factor for such effects to appear (Sajjad Khan et al., 2007; WOCAC, 2003). The rates of inbreeding must be limited to maintain diversity at an acceptable level so that genetic variation will ensure that future animals can respond to changes in environment (Van Wyk et al., 2009). However, non-random mating of animals was the primary reason for choosing the phenotypes instead of generating meaningful BLUP (best linear unbiased prediction) but detailed studies of researchers (Sajjad Khan et al., 2007) indicated that genetic trends in most traits were close to zero and therefore phenotypes were chosen instead of BLUP estimates to report the effect of inbreeding. The genetic breeding values of animals for different traits are usually used as criteria for selecting the best sires and dams and animal breeding emphasis on them can increase the inbreeding coefficient, because relationship between animals tend to provide similar genetic values, having as a consequence the selection of the most frequent relatives (Pedrosa et al., 2010; Eteqadi et al., 2014). The intensity of selection is often raised by applying reproductive technologies being concentrated on a few superior animals (especially sires) and the use of advanced genetic evaluation methods (Eteqadi et al., 2014). Several biological and methodological variables exist that determine the estimated inbreeding effect on performance traits. It is well known that both positive effects of inbreeding and negative ones exist. Therefore, in a given population, bad and good inbreeding impacts are usually mixed (Barczak et al., 2009; Eteqadi et al., 2014).

Conclusion

Effect of inbreeding on reproductive traits in this breed was very pronounced in the flock. Some of the traits such as LMWLB showed deterioration due to inbreeding while some improvement was observed due to inbreeding in LSB, LSW, LMWLW and TLWW. The continuous rise in the level of inbreeding over the years warns that matings in the future should be more planned to avoid matings of close relatives. Because, as already noted, increment of inbreeding increases homozygosity, which reduces the performance of production traits over time, causes the effects of harmful recessive alleles appearing in economically important traits. Therefore, increase in number of breeding males and their frequent replacement would help to reduce the level of inbreeding. However, the results of the present study did not support only negative effects of inbreeding to impact on reproduction traits. Both positive and negative inbreeding effects were found in the current study.

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