

Inbreeding effects on body weight traits of Iranian Moghani sheep

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Abstract

The objective of the present study was to evaluate the effects of inbreeding on body weight at different ages in Moghani sheep. Traits included were birth weight (BW), 3-month weight (3MW), 6-month weight (6MW), 9-month weight (9MW), and yearling weight (YW). Data and pedigree information used in this study were collected at the Breeding Station of Moghani sheep, Iran during 1987-2005. All the animals were grouped into three classes according to the inbreeding coefficients obtained by their pedigree: the first class included non-inbred animals ($F=0\%$); and the second and third classes included inbred animals ($0<F\leq 0.10$ and $F>0.10$, respectively). Average inbreeding rate was 2.93% in the pedigree of Moghani sheep. The BW of animals within second class of inbreeding was significantly higher than those of lambs belonging to the third class ($P<0.05$). The 3MW of animals within third class of inbreeding was significantly ($P<0.05$) higher than those of lambs belonging to the first and second classes. The 6MW of animals within third class of inbreeding was significantly ($P<0.05$) lower than those of lambs belonging to the first and second classes. Animals within third class of inbreeding had greater mean of 9MW than two other groups ($P<0.05$). Also, the YW of animals within second class of inbreeding was significantly ($P<0.05$) lower than those of lambs belonging to the first and third classes. The utilization of designed mating system could be a suitable approach to maintain the level of inbreeding under control.

Keywords: fat-tailed sheep, growth trait, inbreeding depression

Introduction

One definition for inbreeding is given by the mating of individuals whose relatedness between them is greater than the average degree of relationship existing in the population (Lush 1945), and capable of changing the genotypic frequencies of a population without modifying the gene frequencies. Most inbreeding results from the intensive use of a few breeding animals, where the selection intensity is high. Thus, a small number of seedstock, with a strong family relationship, is responsible for the maintenance of almost the whole genetic pool in the population. This is an aspect of great influence in the genealogical analysis of a population structure, because of its effect on the probability of genes lost between generations and the consequent reduction in genetic variability (Pedrosa *et al.* 2010).

Heterozygosity and allelic diversities can be lost from small, closed, selected populations at a rapid rate. The loss of diversity and resulting increase in homozygosity may result in decreased productions and/or fitness of inbred animals. Furthermore, inbreeding depression

in domestic animals can lead to a decrease in selection response and in potential genetic gains in economic traits. Measurement of the effect of inbreeding on these traits is important in order to estimate the magnitude of change associated with increases in inbreeding. The inbreeding depression has been well documented in many populations for a variety of traits (Lamberson & Thomas 1984, Ercanbrack & Knight 1991, Analla *et al.* 1998, Dario & Bufano 2003, Khan *et al.* 2007, Van Wyk *et al.* 2009). Inbreeding impairs growth, productions, health, reproduction traits (such as fertility) and survival. The emergence of disorders due to recessive gene action may also occur. It is apparent that different breeds and populations, as well as different traits vary in their response to inbreeding. Some populations may show a very pronounced effect of increased inbreeding for a trait, whereas others may not demonstrate much of an effect (Negussie *et al.* 2002, Barczak *et al.* 2009).

The rate of inbreeding needs to be limited to maintain diversity at an acceptable level so that genetic variation will ensure that future animals can respond to changes in the environment and to selection. Without genetic variation, animals cannot adapt to these changes (Van Wyk *et al.* 2009). The objective of this study was to evaluate the effects of inbreeding on different weights of Iranian Moghani sheep over a 19-year period from 1987 to 2005.

Material and methods

Data and pedigree information

Moghani breed, numbering about 5.5 million, is one of the most important meat breeds among Iranian sheep. They are well-known for their large size, tolerance to climatic changes and capability to produce heavy lambs (Shodja 2006). The breed is fat-tailed, its coat colour is predominantly white and its face, legs and feet are brown. In this breed, both sexes are polled. A breeding station of Moghani breed was established in 1952 in Ardebil province of Iran in order to genetically improve the performance of Moghani sheep, through identifying the best rams and distributing them to the commercial flocks. Body weights at birth, weaning and at higher ages were sometimes considered as criteria in selection of replacements. Data and pedigree information used in this study were collected at the breeding station of Moghani sheep from 1987 to 2005. The included traits were: birth weight (BW), 3-month weight (3MW), 6-month weight (6MW), 9-month weight (9MW), and yearling weight (YW). The CFC program (Sargolzaei *et al.* 2006) was used to calculate pedigree statistics and regular inbreeding coefficients for individuals in the pedigree. The number of animals (in total), inbred animals, sires, dams, founders and non founders in the pedigree of Moghani sheep were 8494, 1060, 625, 2828, 1835 and 6659, respectively. Also, there were totally 1210 full-sib groups with average family size of 2.12 in the pedigree of Moghani sheep. On the basis of individual inbreeding coefficient, all the animals were grouped in three classes: first class including non-inbred animals ($F=0$); second and third classes including inbred animals ($0 < F \leq 0.10$ and $F > 0.10$, respectively). The incidences of triplets and quadruplets were so low ($< 0.8\%$) that records from lambs born in triplet and quadruplet litters were discarded.

Statistical analysis

The effects of inbreeding rate on body weight traits were analysed using the linear mixed model (Proc Mixed) with the best fitted covariance structure of SAS 9.1 (SAS Institute Inc., Cary, NC, USA). The least-squares means were estimated by restricted maximum likelihood (REML) method. Level of significance for the inclusion of effects into the model of analysis was declared at $P < 0.05$. The final model included the fixed class effects of year-season (76 levels), inbreeding class, sex of lamb, parity of dam, litter size (single and twin), age of dam (from 2 through 7 years old) and random effect of animal. All the interactions of first order were included in the preliminary models, but only sex by parity, litter size by inbreeding class, sex by inbreeding class and litter size by parity interaction effects were kept in the final models. Trend of inbreeding was estimated using the linear regression of individual inbreeding on birth year. Also, inbreeding depression was estimated as the regression of body weight traits on the individual inbreeding coefficients.

Results

The analysis of pedigree revealed that inbreeding rate ranged from 0 to 28.13 % with an average of 2.93 %. Figure 1 shows the average of inbreeding coefficients over years. The trend of inbreeding was significantly positive over the years ($P < 0.05$) and its estimate was 0.027 ± 0.011 . Table 1 shows the summary statistics for body weight traits in different inbreeding classes of animals. The BW of animals within second class of inbreeding was higher than those of lambs belonging to the first and third classes, but only differences were

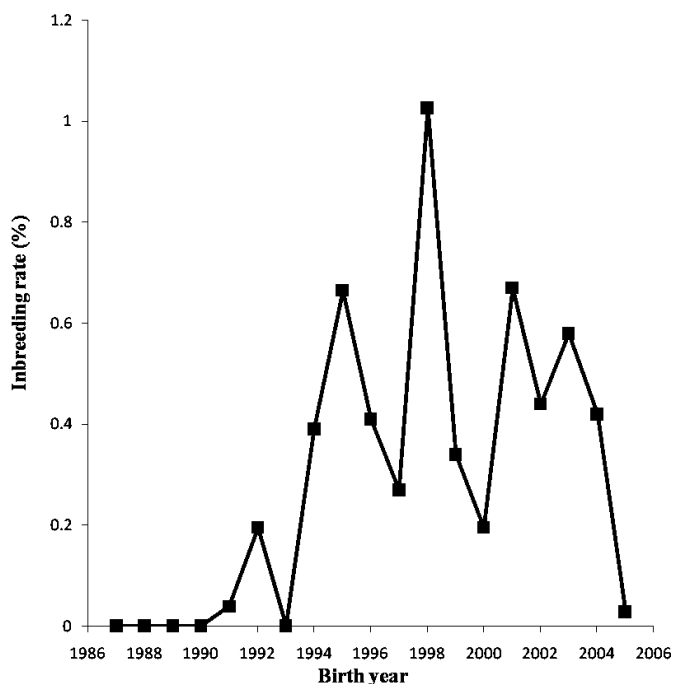


Figure 1
Distribution of inbreeding rate, %
over the years

significant only between second and third classes ($P<0.05$). The 3MW of animals within third class of inbreeding was significantly ($P<0.05$) higher than those of lambs belonging to the first and second classes but there was no significant differences between the first and second classes of inbreeding. On the other hand, the 6MW of animals within third class of inbreeding was significantly ($P<0.05$) lower than those of lambs belonging to the first and second classes. There were significant differences between three classes of inbreeding on 9MW and animals within third class of inbreeding had greater mean of the trait than two other groups ($P<0.05$). Also, the YW of animals within second class of inbreeding was significantly ($P<0.05$) lower than those of lambs belonging to the first and third classes.

Table 1

Distribution of records for body weight traits in different inbreeding classes of animals born between 1987 and 2005

Inbreeding class	BW, kg		3MW, kg		Trait 6MW, kg		9MW, kg		YW, kg	
	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD
F=0	5564	4.56 \pm 0.08 ^{ab}	3240	23.13 \pm 0.55 ^a	2485	34.44 \pm 1.01 ^a	1843	38.45 \pm 0.46 ^b	1076	39.82 \pm 0.46 ^a
0<F \leq 0.10	945	4.62 \pm 0.08 ^b	860	23.98 \pm 0.57 ^a	573	34.89 \pm 1.04 ^a	345	36.85 \pm 0.50 ^a	235	37.66 \pm 0.46 ^b
F>0.10	94	4.48 \pm 0.11 ^a	61	24.77 \pm 0.74 ^b	50	32.85 \pm 1.24 ^b	40	39.80 \pm 0.82 ^c	20	40.99 \pm 0.46 ^a

^{a,b,c}Means within a column that do not have a common superscript are significantly different ($P<0.05$). BW: birth weight, 3MW: 3-month weight, 6MW: 6-month weight, 9MW: 9-month weight, YW: yearling weight

Table 2

Distribution of records for body weight traits in different inbreeding classes of animals grouped by the type of birth and born between 1987 and 2005

Birth type	Inbreeding class	BW, kg		3MW, kg		Trait 6MW, kg		9MW, kg		YW, kg	
		N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD
Single	F=0	1870	4.85 \pm 0.69 ^a	1898	24.71 \pm 4.66 ^a	1485	36.00 \pm 6.22 ^{ab}	1242	39.01 \pm 6.05 ^{ab}	720	40.45 \pm 7.22 ^a
	0<F \leq 0.10	498	4.97 \pm 0.65 ^a	485	25.70 \pm 5.25 ^a	329	34.44 \pm 5.95 ^b	215	37.85 \pm 5.51 ^b	153	38.15 \pm 5.62 ^a
	F>0.10	36	4.85 \pm 0.80 ^a	36	25.13 \pm 5.83 ^a	30	37.70 \pm 7.03 ^a	29	40.56 \pm 5.67 ^a	17	40.72 \pm 6.92 ^a
Twin	F=0	1299	4.15 \pm 0.63 ^a	1342	21.11 \pm 4.74 ^b	1000	32.50 \pm 5.89 ^a	601	37.28 \pm 5.67 ^a	356	38.07 \pm 6.92 ^a
	0<F \leq 0.10	387	4.15 \pm 0.61 ^a	375	21.75 \pm 4.60 ^b	244	30.69 \pm 5.29 ^a	130	35.20 \pm 5.36 ^a	82	36.76 \pm 5.48 ^a
	F>0.10	30	4.02 \pm 0.85 ^a	25	24.32 \pm 4.07 ^a	20	31.22 \pm 4.49 ^a	11	37.93 \pm 7.15 ^a	3	42.46 \pm 8.51 ^a

^{a,b}Means within a column and for each birth type that do not have a common superscript are significantly different ($P<0.05$). BW: birth weight, 3MW: 3-month weight, 6MW: 6-month weight, 9MW: 9-month weight, YW: yearling weight

Single- or twin-born lambs showed no significant differences in their BW and YW irrespective of the inbreeding rate (Table 2). In addition, single-born lambs showed no significant differences in their 3MW. But twin-born lambs in the third class of inbreeding had greater 3MW than those of twin-born lambs belonging to the first and second classes ($P<0.05$). Although twin-born lambs showed no significant differences in their 6MW and 9MW, single-born lambs in the third class of inbreeding showed significant differences on 6MW and 9MW with lambs belonging to the second class (Table 2).

Male lambs showed no significant differences in their BW, 9MW and YW irrespective of the inbreeding rate (Table 3). The 3MW and 6MW of male lambs within third class of inbreeding was significantly higher than those of male lambs belonging to the first and second classes

($P<0.05$). Female lambs showed no significant differences in their 3MW irrespective of the inbreeding rate. The BW and 9MW of female lambs in third class of inbreeding were significantly different with those of two other groups ($P<0.05$). The 6MW of female lambs within first class of inbreeding was significantly ($P<0.05$) greater than that of female lambs belonging to the second class. On the other hand, the YW of female lambs within third class of inbreeding was significantly ($P<0.05$) greater than that of female lambs belonging to the second class.

Table 3

Distribution of records for body weight traits in different inbreeding classes of animals grouped by the sex of lamb and born between 1987 and 2005

Lamb sex	Inbreeding class	BW, kg		3MW, kg		Trait 6MW, kg		9MW, kg		YW, kg	
		N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD
Male	F=0	1603	4.36 \pm 0.70 ^a	1641	22.09 \pm 4.44 ^b	1235	32.28 \pm 5.24 ^b	902	36.41 \pm 5.26 ^a	462	39.84 \pm 7.41 ^a
	0<F \leq 0.10	479	4.46 \pm 0.72 ^a	459	22.73 \pm 4.78 ^b	296	31.22 \pm 5.06 ^b	161	35.05 \pm 4.85 ^a	114	37.03 \pm 5.01 ^a
	F>0.10	34	4.54 \pm 0.94 ^a	31	24.83 \pm 3.96 ^a	28	34.47 \pm 5.35 ^a	20	36.32 \pm 5.15 ^a	7	39.62 \pm 4.85 ^a
Fem.	F=0	1600	4.73 \pm 0.77 ^a	1627	24.30 \pm 5.31 ^a	1271	36.78 \pm 6.50 ^a	953	40.32 \pm 5.98 ^b	622	39.47 \pm 7.03 ^{ab}
	0<F \leq 0.10	427	4.73 \pm 0.81 ^a	418	24.11 \pm 5.70 ^a	286	34.31 \pm 6.48 ^b	187	38.27 \pm 5.85 ^b	124	38.05 \pm 6.22 ^b
	F>0.10	32	4.41 \pm 0.89 ^b	30	24.76 \pm 6.22 ^a	22	35.92 \pm 8.51 ^{ab}	20	43.36 \pm 4.96 ^a	13	41.72 \pm 7.94 ^a

^{a,b}Means within a column and for each lamb sex that do not have a common superscript are significantly different ($P<0.05$). BW: birth weight, 3MW: 3-month weight, 6MW: 6-month weight, 9MW: 9-month weight, YW: yearling weight

Table 4

Regression coefficients (\pm SE) of body weight traits on inbreeding of lambs for a change of 1 % in inbreeding

Item	BW		3MW		Traits 6MW		9MW		YW	
Single	–0.009 \pm 0.006		0.007 \pm 0.047		–0.029 \pm 0.068		0.003 \pm 0.065		–0.183 \pm 0.105***	
Twin	–0.012 \pm 0.006***		0.129 \pm 0.057**		–0.128 \pm 0.078		–0.166 \pm 0.105		–0.092 \pm 0.191	
Male	0.009 \pm 0.007		0.126 \pm 0.048**		0.081 \pm 0.062		–0.071 \pm 0.071		–0.357 \pm 0.155*	
Female	–0.025 \pm 0.008**		–0.020 \pm 0.058		–0.234 \pm 0.079**		–0.025 \pm 0.078		–0.030 \pm 0.116	
All	–0.009 \pm 0.005***		0.057 \pm 0.040		–0.079 \pm 0.056		–0.045 \pm 0.059		–0.159 \pm 0.095***	

*significant at $P<0.05$, **significant at $P<0.01$, ***trend for significance ($0.05<P<0.10$). BW: birth weight, 3MW: 3-month weight, 6MW: 6-month weight, 9MW: 9-month weight, YW: yearling weight

Table 4 shows the regression coefficients of body weights on inbreeding of lambs for a change of 1 % in inbreeding. There were trends for significance for the regression coefficients of BW and YW on inbreeding of all lambs. The regression coefficients of birth and yearling weights on lamb inbreeding were estimated to be -0.009 ± 0.005 and -0.159 ± 0.095 ($P<0.08$), respectively, then birth and yearling weights decreased respectively by 0.009 kg and 0.159 kg due to 1 % increase in inbreeding. The regression coefficient of 3MW on inbreeding of lambs for change of 1 % in inbreeding was positive and non significant, but the coefficients of 6MW and 9MW were negative and non significant. Considering the birth type, the regression coefficient of 3MW on inbreeding of twin-born lambs was significantly positive (0.129 ± 0.057 , $P<0.01$). Therefore, 3MW of twins increased 0.129 kg due to 1 % increase in inbreeding. There were trends for significance for the regression coefficients of YW in single-born lambs and BW in twin-born lambs and their corresponding values were -0.183 ± 0.105 and -0.012 ± 0.006 , respectively ($P<0.10$). Also, considering the sex of lambs, the 3MW and YW of male lambs

increased and decreased respectively by 0.126 kg ($P<0.01$) and 0.357 kg ($P<0.05$) due to 1 % increase in inbreeding. On the other hand, the BW and 6MW of female lambs decreased respectively by 0.025 kg ($P<0.01$) and 0.234 kg ($P<0.01$) due to 1 % increase in inbreeding.

Discussion

The inbreeding level estimates are strongly determined by the two main factors: depth and completeness of pedigree and selection intensity. Selection intensity is often increased by the reproductive technologies being focused on a few superior animals (especially sires) and the application of advanced methods of genetic evaluation. A high inbreeding level is observed for populations rebuilt from small number of founders, but on the other hand in this case the accuracy is strongly determined by the incompleteness of pedigrees (Barczak *et al.* 2009). Consistent with the result of this study, Pedrosa *et al.* (2010) reported the average inbreeding was 2.33 % in Santa Inês sheep in Brazil. But, Van Wyk *et al.* (2009) and Selvaggi *et al.* (2010) reported higher inbreeding rates in Elsenburg Dormer sheep (16 %) and Leccese sheep (8.1 %), respectively. The rapid increase in the rate of inbreeding in 1994 and 1998 could be resulted from the decrease in the number of sires. Also, some animals of the studied population had presented high levels of inbreeding, reflecting the intensive use of few sires. Similar to the current results, Barczak *et al.* (2009) reported positive trend for inbreeding over the years.

There are several methodological and biological factors which determine the estimated inbreeding impact on performance traits. It is well known that both negative effects and positive ones exist. Hence, in a given population, »bad« and »good« inbreeding effects are mixed (Barczak *et al.* 2009). Similar to the current results, Van Wyk *et al.* (1993) who observed a reduction of 0.008 kg in BW for a 1 % increase of inbreeding in Dormer sheep, Ercanbrack and Knight (1991) who found a mean value of -0.010 kg, Khan *et al.* (1995) and Mirza *et al.* (1999) who reported a regression coefficient of -0.008 and -0.007 respectively. Also, similar to the present study, Barczak *et al.* (2009) reported for sheep of eight lines and breeds an average estimate of -0.0095 kg. MacKinnon (2003) obtained inbreeding depression results of -0.012 kg for crossed sheep and Van Wyk *et al.* (2009), -0.006 kg for the Elsenburg Dormer sheep breed. Causes of variation in inbreeding effects could be due to differences among breeds in alleles segregating, amount of genetic variation in the base population, location, management, and diversity of the founders in the flocks tested (MacKinnon 2003).

Similar to the current results, Lamberson & Thomas (1984) reported no significant reduction of 3MW due to inbreeding in different breeds of sheep. The 3MW of twins and or male lambs was increased due to 1 % increase in lamb inbreeding rate and inconsistent with the current result, Van Wyk *et al.* (2009) and Selvaggi *et al.* (2010) reported significant reduction in 3MW of lambs due to 1 % increase in inbreeding. Lamb sex was a significant effect in the current analysis of inbreeding, but it should be noted that negligible differences between males and females was observed in the study of Barczak *et al.* (2007). Barczak *et al.* (2009) reported positive inbreeding effects on fourth week weight in a multi-breed sheep population. Also, the 6MW of female lambs was reduced 0.234 kg per 1 % increase in inbreeding and similar to this result Pedrosa *et al.* (2010) reported a decrease of 0.204 kg in weight at 180 days due to 1 % increase in inbreeding. To my knowledge, there was no

published report regarding to the effect of inbreeding on YW, but the results of this study indicated a significant reduction in YW of male lambs (0.357 kg) and a trend for significance for the effect of inbreeding on the YW of all lambs. The explanation for the strong inbreeding depression observed for YW in this study was the lower heritability of this trait compared to other weight traits of Moghani sheep (Ghavi Hossein-Zadeh & Ardalan 2010), since traits of low heritability tend to show less additive genetic variation and more dominance deviation than more heritable traits (Lamberson & Thomas 1984).

In conclusion, average inbreeding rate was 2.93 % in Iranian Moghani sheep and an increasing trend for inbreeding was observed over the years. Both positive and negative inbreeding effects were found in the current study. From the results of this study it can be seen that there was a trend for the negative effects of inbreeding on the BW and YW of all lambs but the regression coefficients of other body weight traits on inbreeding of all lambs for a change of 1 % in inbreeding were not significant. The results of this study indicated a significant reduction in YW of male lambs, but the 3MW of twins and or male lambs was increased due to 1 % increase in lamb inbreeding rate. Although inbreeding depression was not generally a possible cause of the reduction in the growth performance of Iranian Moghani sheep until now, but the utilization of designed mating system, at the current flock, could be a suitable approach to maintain the level of inbreeding under control.

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