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Original Article

Studies on inbreeding and its effects on growth traits of Iran-Black sheep

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Abstract

Data and pedigree information of 5173 Iran-Black sheep, maintained at the breeding station of Abbasabad, Iran, for a period of 25 years (1980 through 2004) were used to determine the level of inbreeding of the animals as well as to quantify the effect on the growth traits of the animals. The individual (and maternal) inbreeding depression of the animals was investigated by fitting the inbreeding coefficient of the lambs (and the ewes) as linear covariates under univariate animal models. The mean inbreeding for the ewes, whole population, females, and males, were 6.55%, 7.54%, 7.72%, and 7.36%, respectively, in the flock. The individual inbreeding depression per 1% increase in the inbreeding ranged from -3.4 (birth weight) to -44.3 g (9-month body weight), whereas the maternal inbreeding depression varied from -12.6 to -80.7g for the weights at birth and six months of age, respectively. The present results showed that inbreeding depression significantly reduced the body weights of lambs in this breed. Since the level of inbreeding of the lambs had a detrimental effect on growth traits, there is a need to control the inbreeding in the flock.

Keywords: Iran-Black, growth traits, inbreeding trend, inbreeding depression

1. Introduction

Inbreeding is defined as the probability that two alleles at any locus are identical by descent (Falconer & Mackay, 1996) and occurs when related individuals are mated to each other. Inbreeding depression can be expressed as the change in performance per unit of inbreeding. The level of inbreeding is an important genetic property of any population and needs to be known as it can influence breeding decisions and the design of livestock genetic improvement programs. Selection in closed populations results in gradual inbreeding due to mating of relatives. In fact, inbreeding increases homozygosity for whatever genes are present, including the less desirable ones, and has been associated with a decline in performance. Moreover, inbreeding can lead to a decrease in response to selection and consequently in genetic improvement of economically important traits (Ghavi Hossein-Zadeh, 2013). Inbreeding depression must be restricted at a critical level to make ensure that future animals can respond to changes in the environment (Van Wyk Fair & Cloete, 2009). Several reports showed the inbreeding depression affects the growth and reproductive performance of sheep breeds (Barczak, Wolc, Wójtowski, Slósarz, & Szwaczkowski, 2009; Dorostkar *et al.*, 2012; Mokhtari, Shahrbabak, Esmailizadeh, Shahrbabak, & Gutierrez, 2014; Norberg & Sørensen, 2007;

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Van Wyk *et al.,* 2009). Scanty reports are available on the effect of inbreeding depression on post-weaning traits of Iran-Black sheep. Therefore, the objective of the present study was to assess the level of inbreeding over time and to determine the effect of inbreeding depression on body weight, average daily weight gain (ADG), and the Kleiber ratio at different stages of growth in Iran-Black sheep.

2. Materials and Methods

2.1 Animal and data structure

Iran-Black sheep, the first synthetic sheep breed in Iran that resulted from a cross of Chios rams with Iranian Balouchi ewes (Mokhtari *et al.,* 2014), are maintained at a breeding station in Abbasabad located in the northeastern part of Iran. This breed is well adapted to the arid and hot climate in that part of the country. The environmental condition of the study area was similar with the location described by Rashidi (2012). The main purpose of developing this breed was to improve the litter size, weaning performance, and tolerance to harsh environmental conditions (Mokhtari *et al.,* 2014) and to disseminate the genetically superior animals into local flocks to improve the production efficiency (Rashidi, 2012). The animals mate from mid-August to September with a mating ratio of one breeding ram to 10-12 ewes. Lambing starts in mid-January and ends in February (Kamjoo, Baneh, Yousefi, Mandal, & Rahimi, 2014). The breeding rams are used for 5 years and ewes up to 6 years. The lambs are weighed and ear-tagged shortly after birth and weaned at 90 days of age. From birth to 12 months of age, the lambs are weighed at three-month intervals, and the date of each weighing is recorded.

A pedigree file of 5173 animals of Iran-Black sheep, that were maintained at the Abbasabad breeding station (northeast of Mashhad, Khorasan Razavi Province of Iran) for a period of 25 years (1980-2004) were used to compute the inbreeding coefficient of each animal. The body weights of the lambs for this study were birth weight (BW), 3-month weight (3MW), 6-month weight (6MW), 9-month weight (9-MW), and yearling weight (YW). The average daily weight gain (ADG) at different stages of growth, i.e. weight gain from 0 to 3 months of age (ADG0-3), from 3 to 6 months of age (ADG3-6), and from 6 to 12 months of age (ADG6-12), was considered for this study. The Kleiber ratio, defined as the growth rate/metabolic weight as suggested for measuring growth efficiency (Kleiber, 1947), was used as an alternative ratio to select animals for breeding. Therefore, the Kleiber ratios at different ages, i.e. 0-3 months of age [KR0-3= ADG0-3/((3MW)$^{0.75}$], 3-6 months of age [KR3-6=ADG3-6/((6MW)$^{0.75}$)] and 6-12 months of age [KR6-12=ADG6-12/((YW)$^{0.75}$)] were also included for the present study.

The number of records for BW, 3MW, 6MW, 9-MW, YW, ADG0-3, ADG3-6, ADG6-12, KR0-3, KR3-6 and KR6-12 were 4607, 4220, 3636, 2954, 3872, 3591, 2944, 3872, 3591, and 2944, respectively.

2.2 Computation of pedigree completeness index and inbreeding coefficients

Since the quality of pedigree information is of great importance in assessing the levels of inbreeding and trends in inbreeding, the pedigree completeness index (PCI) as proposed by MacCluer *et al.* (1983) was computed from the following formula:

$$\mathrm{PCI} = \frac{4C_{\mathrm{sire}}C_{\mathrm{dam}}}{C_{\mathrm{sire}} + C_{\mathrm{dam}}}$$

where, C_{sire} and C_{dam} are contributions from the paternal and maternal lines, respectively. The contributions were computed as:

$$C = \frac{1}{d}\sum_{i=1}^{d} a_i$$

where a_i is the proportion of known ancestors in generation i; and d is the number of generations taken into account. In this study, 5 generations were considered when calculating the average PCI for each animal (d=5) according to the birth year (Norberg & Sorenson, 2007). EVA software was used to compute this index (Berg, Sørensen, & Nielsen, 2007). The average number of discrete generation equivalents (EqCG) was computed following Maignel, Boichard and Verrier (19 96) using the formula: EqCGi=$\Sigma(1/2)^n$ where n is the number of generations separating the individual from each known ancestor. The co-ancestry coefficients and the expected inbreeding under random mating were calculated using EVA software (Berg *et al.*, 2007).

Inbreeding coefficients for all animals were calculated by a modification of Colleau's indirect algorithm (Sargolzaei, Iwaisaki, & Colleau, 2005) using CFC software (Sargolzaei, Iwaisaki, & Colleau, 2006). Animals that had an inbreeding coefficient greater than zero were considered to be inbred animals. Based on the individual inbreeding coefficient, all animals were classified in five groups. The first group was made up of non-inbred animals (F=0). The second, third, fourth, and fifth groups were inbred animals with various degrees of inbreeding ($0<F<6.25$, $6.25<F<12.5$, $12.5<F<18.75$, and $F\geq18.75$ %, respectively).

To estimate the inbreeding effect on studied traits, the data were filtered by PCI criteria as proposed by Norberg and Sorenson (2007) and Dorostkar *et al.* (2012). Several authors have proposed a range of PCI from 0.3 (Dorostkar *et al.*, 2012) to 0.9 (Norberg & Sorenson, 2007). In the current study, animals with PCI >0.7 were considered for this analysis as having enough available data when the cut-off of the PCI was 0.7.

2.3 Statistical analyses

The generalized linear models (GLM) procedure (SAS Institute Inc., 2002) was initially used to determine the effects of different non-genetic factors on body weights, ADG, and the Kleiber ratio of Iran-Black sheep at different ages. The different non-genetic effects included in the model were sex (male and female), year of birth (24 classes), age of dam at lambing (2, 3, 4, 5, 6, and 7 years old) and type of birth (single, twin, and triplet). The age of lambs at weaning (in days) was considered as covariate for 9MW and YW. Non-significant interaction effects were removed from the final models of analysis. For inclusion of fixed effects into the final model, the significance level was set at P<0.05. To estimate the effects of the individual and maternal inbreeding on the studied traits, the inbreeding coefficient of the lamb and the ewes were considered in the model as linear covariates for all traits. The individual (maternal) inbreeding depression for each trait was estimated as a decrease in the trait per 1% increase in individual (maternal) inbreeding coefficient. The significant random effects affecting growth traits of this breed as obtained by Kamjoo *et al.* (2014) were considered for the present analysis. They stated that growth traits in this breed are mainly affected by direct genetic, maternal genetic as well as maternal permanent environmental effects. Therefore, the following model was used for investigated traits:

$$\mathbf{y=Xb+Z_1a+Z_2m+Z_3pe+e}$$

where **y** is a vector of phenotype observation for the traits; **b**, **a**, **m**, **pe**, and **e** are vectors of fixed, direct genetic, maternal genetic, maternal permanent environmental and the residual effects, respectively. **X**, $\mathbf{Z_1}$, $\mathbf{Z_2}$, and $\mathbf{Z_3}$ are design matrices associating the corresponding effects to vectors of **y**. The statistical analyses were carried out by AI-REML algorithm using the WOMBAT program (Meyer, 2007).

3. Results

3.1 Pedigree completeness and level of inbreeding

The completeness of pedigree for Iran-Black sheep is depicted in Figure 1. In the present study, the completeness of pedigree was high and this value for 5 generations was approximately 0.57. Besides, the value of completeness of pedigree increased with the accuracy on inbreeding coefficient estimation. The average value of PCI for 1994-2004 was 0.77. Moreover, the trend of PCI for all investigated years increased for this flock. The changes in mean inbreeding level, expected inbreeding under random mating, and co-ancestory over the studied years are presented in Figure 2. In all of the years, the averages of observed inbreeding were higher than the expected inbreeding under random mating but lower than average coancestry in the present study. Nevertheless, their undulating patterns were similar and they were closer to each other in the latter years.

The present study revealed that the pedigree used in this study was of relatively good quality since both parents were known in 94.43% (n=4885) of the animals (Table 1). Both parents were unknown in 135 (2.61%) foundation animals. Out of the whole population, 79.34% of the animals was inbred (Table 1) with the average inbreeding coefficient of 9.5% (Table 2). The maximum, minimum, and mean inbreeding level for all animals, females, and males for the entire population, inbred population, ewes, and inbred ewes over the study period are shown in Table 2. There was a more or less linear increase in inbreeding level for male and female animals during 1980-2004. However, the mean inbreeding coefficient for males and females was always the same. It seems that the use of large numbers of sons and grandsons of a few outstanding sires of earlier periods might be associated with the increase in inbreeding rates for animals in this flock.

Descriptive statistics for the studied traits and distribution of animals in different classes of inbreeding are shown in Table 3. The number of records for studied traits decreased from birth to yearling. The number of sires and dams for traits mentioned were minimally different. The incidences of triplets and quadruplets were low. Therefore, the records of lambs born in triplet and quadruplet litters were discarded.

Table 4 shows the distribution of animals with different inbreeding levels during the 25 years. In the flock, 35. 6% of the animals had an inbreeding level of 6.25<F<12.5. As the rate of inbreeding increased, the percentages of inbred animals essentially declined. The mean inbreeding level for inbred ewes was slightly lower than all inbred animals. The minimum level of inbreeding for inbred animals (ewes, males,

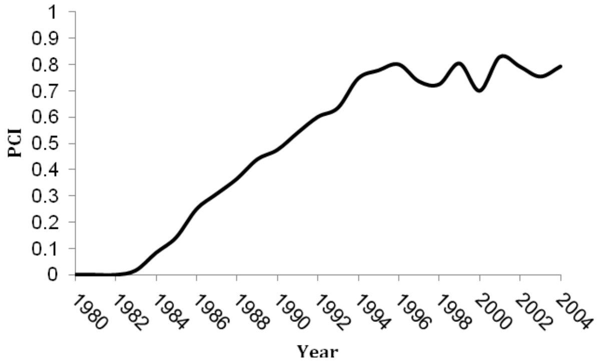

Figure 1. Average pedigree completeness indices (PCI) for each birth year of Iran-Black sheep.

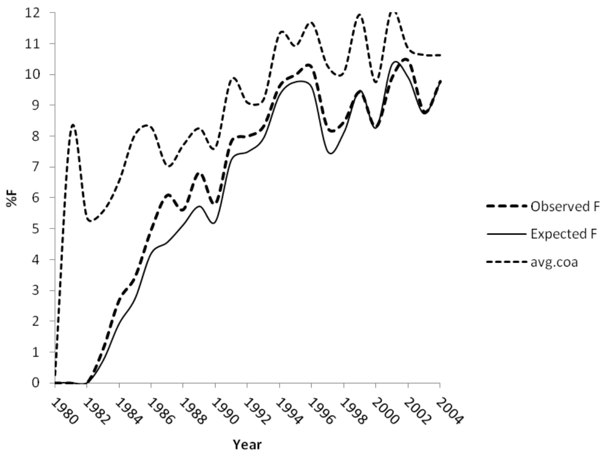

Figure 2. Annual mean of observed inbreeding, expected under random mating and average coancestry.

Table 1. Pedigree information of Iran-Black sheep.

	Number	% of total
Animals in pedigree	5173	100
Inbred	4104	79.34
Non Inbred	1069	20.66
Animals with offspring	1328	25.67
Animals without offspring	3845	74.33
Animals with both parents unknown (foundation animals)	135	2.61
Animals with only known sire	1	0.02
Animals with only known dam	152	2.94
Animals with both parents known	4885	94.43

Table 2. Descriptive statistics for the studied traits and distribution of animals in different classes of inbreeding.

Trait	BW (kg)	3MW (kg)	6MW (kg)	9MW (kg)	YW (kg)	ADG0-3 (g)	KR0-3	ADG3-6 (g)	KR3-6	ADG6-12 (g)	KR6-12
Mean	3.61	22.13	29.17	33.2	39.39	183.22	17.86	80.74	6.27	50.89	3.15
No. of records	4,607	4,220	3,636	3,195	2,954	3,872	3,872	3,591	3,591	2,944	2,944
SD	0.83	5.19	5.67	5.71	7.05	47.57	1.76	50.64	3.77	27.79	1.53
Min	1.2	8	12.66	19	20	33.6	6.83	-108.38	-11.01	-61.15	-5.02
Max	6.4	39.71	48.5	52	67	359.1	22.83	353.75	21.91	195.46	9.81
No. of sires	122	142	138	119	119	122	122	138	138	119	119
No. of dams	1161	1140	1079	1024	1006	1103	1103	1075	1075	1004	1004
F=0	517	728	645	593	542	390	390	638	638	540	540
0<F<6.25	1155	978	850	736	679	975	975	836	836	679	679
6.25<F<12.5	1843	1591	1354	1189	1085	1589	1589	1337	1337	1078	1078
12.5<F<18.75	759	637	550	478	459	636	636	545	545	458	458
F≥18.75	333	286	237	199	189	282	282	235	235	189	189

BW=birth weight, 3MW=3-month weight, 6MW=6-month weight, 9MW=9-month weight, YW= yearling weight, ADG0-3=average daily gain from 0 to 3 months of age, ADG3-6=average daily gain from 3 to 6 months of age, ADG6-12=average daily gain from 6 to 12 months of age, KR0-3=Kleiber ratio from 0 to 3 months of age, KR3-6=Kleiber ratio from 3 to 6 months of age, KR6-12=Kleiber ratio from 6 to 12 months of age, F=Inbreeding coefficient (%).

Table 3. Description of inbreeding in Iran-Black sheep.

Population	Animal (n)	Mean (%)	SD (%)	Median (%)	Min (%)	Max (%)
Entire						
Male+Female	5173	7.54	6.59	6.60	0.00	38.48
Male	2552	7.36	6.62	6.79	0.00	38.48
Female	2621	7.72	6.54	6.30	0.00	37.67
Inbred						
Male+Female	4104	9.50	6.00	8.17	0.39	38.48
Male	2063	9.55	6.07	8.20	0.39	38.48
Female	2041	9.45	5.93	8.08	0.39	37.67
Ewes	1216	6.55	6.44	6.19	0.00	35.16
Inbred Ewes	876	9.09	5.87	7.45	0.39	35.16
Sires	112	6.145	6.67	5.251	0.00	25.00
Inbred Sires	67	10.2717	5.64	9.3750	0.7813	25.00

Table 4. Distribution of animals and their inbreeding mean in different classes of inbreeding.

Category	Entire			Male			Female		
	n	%	$\bar{F}$ (%)	n	%	$\bar{F}$ (%)	n	%	$\bar{F}$ (%)
F=0	1069	20.66	0	489	19.16	0	580	22.13	0
0<F<6.25	1160	22.42	3.63	592	23.2	3.61	568	21.67	3.65
6.25<F<12.5	1845	35.67	8.48	916	35.89	8.56	929	35.44	8.4
12.5<F<18.75	761	14.71	14.74	380	14.89	14.78	381	14.54	14.7
F≥18.75	338	6.53	23.43	175	6.86	23.45	163	6.22	23.42

$\bar{F}$: Average of inbreeding coefficients

and females) was 0.039 and the maximum value was 38.48. This was applied to classify the rate of inbreeding in the population (Table 4). The number of inbred animals in the population was 4104, which was comprised of 2063 males and 2041 females. The mean inbreeding for the entire population ranged from 6.55 (ewes) to 9.55 (inbred male lambs). In the class of F≥18.75, the average inbreeding level in males was higher and included 6.86% of all the lambs (Table 4).

The annual average inbreeding level of animals for the entire flock, male, and females over the years is shown in Table 5. A steady increase in the mean inbreeding level was observed and the annual rate of increase in inbreeding from 1980 to 2004 was 0.43% per year.

3.2 Effects of inbreeding on investigated traits

The individual and maternal regression coefficients of the studied traits on inbreeding of all animals for a change of 1% increase in inbreeding are presented in Table 6. The individual regression coefficients of BW, 3MW, 6MW, 9MW,

Table 5. Inbreeding trends in Iran-Black sheep.

Population	Regression coefficient	P value	R^2
Entire	0.43±0.04	<0.0001	0.80
Male	0.43±0.04	<0.0001	0.81
Female	0.42±0.05	<0.0001	0.79

Table 6. Individual and maternal inbreeding depression per 1% increase in inbreeding.

Trait[a]	Regression coefficients (g)	
	IF[b]	MF
BW	-3.4	-12.6
3MW	-32.1	-77.3
6MW	-14.4	-80.7
9MW	-44.3	-72.1
YW	-23.7	-72.5
ADG0-3	-0.27	-0.63
ADG3-6	0.17	-0.28
ADG6-12	0.103	-0.054
KR0-3	-0.008	-0.014
KR3-6	0.021	-0.003
KR6-12	0.007	-0.0002

[a] For traits abbreviations see footnote of Table 2.
[b]IF= Individual inbreeding depression, MF= Maternal inbreeding depression

and YW on inbreeding were -3.4, -32.1, -14.4, -44.3, and -23.7g, respectively. The values for ADG0-3, ADG3-6, and ADG6-12 were -0.27, 0.17, and 0.103 g, respectively. Also, individual inbreeding depressions per 1% increase in inbreeding for KR0-3, KR3-6, and KR6-12 were -0.008, 0.021, and 0.007, respectively. In this study, no definite pattern in the increment of individual inbreeding depression for studied traits with age was observed. However, maximum inbreeding depression for 9MW was noticed among all body weight traits. For the ADG, there was a minimal change (-0.27 g) per 1% increase in inbreeding for ADG0-3. The estimates of inbreeding depression were positive for ADG3-6 and ADG6-12. Individual inbreeding depression per 1% increase in inbreeding for KR3-6 and KR6-12 was also positive (Table 6). Maternal inbreeding depression for studied traits was higher than individual inbreeding depression except for KR3-6 and KR6-12 in the present study.

4. Discussion

Many studies have reported on the pedigree structure and inbreeding depression for growth and reproduction traits in populations of sheep (Dorostkar *et al.,* 2012; Ghavi Hossein-Zadeh, 2013). The estimation of inbreeding for a special population is strongly affected by completeness of pedigree. Therefore, the PCI proposed by MacCluer *et al.* (19 83) is the best tool available to assess the quality and depth of the pedigree of the population. Arnason and Jonmundsson (2008) estimated the PCI of Iceland sheep to be 0.4. The estimated PCI values by Norberg and Sorenson (2007) and Li, Strandén and Kantanen (2009) were 0.6 and 0.9, respectively while Dorostkar *et al.* (2012) estimated a PCI of 0.31 for the Moghani sheep breed. The average number of discrete generation equivalents was 4.22 while the maximum discrete generation equivalents were 8.11. So, this parameter showed that completeness of the pedigree of this population was on a satisfactory level. Our estimate of the mean inbreeding level of 7.54 in the whole population of Iran-Black sheep was lower than 8.08 reported by Mokhtari *et al.* (2014) for this breed during the period of 1980 to 2008. The estimates of Dorostkar *et al.* (2012) for Moghani sheep (0.50%), Jafari (2014) for Makooei Sheep (0.33%), and Swanepoel, Van Wyk, Cloete and Delport (2007) for the Dohne Merino breed in South Africa (0.64%) were lower than our findings. However, the higher estimate of inbreeding compared to the present study was reported by Van Wyk *et al.* (2009) for the Elsenburg Dormer breed (16%). These differences may be due to breed, pedigree size, structure of the population, breeding strategies as well as different levels of pedigree completeness. It is deduced from the maximum inbreeding coefficient for lambs (38.48) and ewes (35.16) that some low matings of close relatives occurred in the population. Similar results have been reported by Jafari (2014) and Dorostkar *et al.* (2012) in other sheep breeds.

In this study, the high proportion of individuals (79. 33%) and ewes (72.04%) were inbred, but there were no sizable differences between their mean inbreeding coefficients and those of whole pedigree (inbred+non-inbred). The estimates of mean inbreeding were 9.50% and 9.55% for inbred lambs and dams, respectively. These values were close to those of estimates for whole lambs (7.54%) and whole dams (6.55%). These differences were not very meaningful. Animals with high inbreeding coefficients (F) have a low frequency and those with low ones are frequent. Also, the maximum proportion of animals from the whole population (35.67%), male (35.89%) and female (35.44%) showed an inbreeding level of $6.25<F<12.5$. In the present study, the rapid increase in the rate of inbreeding that occurred from 1982 to 1994 might have resulted from the decrease in the number of sires used over the years and high levels of inbreeding of some animals in the flock. During the reproductive season, each breeding ram was exposed to 10-12 ewes and it was supposed that the average number of progeny per ram would be about 30 lambs. But since some rams were kept for a longer period of time (up to 5 years) in the flock for reproductive service, the average progeny per sire (in whole pedigree) was 43.24 lambs. This fact may be the main cause of increasing the inbreeding level in the population. However, the trend of inbreeding levels over the years for the present study was positive (0.43%) which was in accordance with the findings of Barczak *et al.* (2009), who reported a positive trend for inbreeding over the years. Mokthrai *et al.* (2014) also reported a similar positive (0.41%) trend of inbreeding over the years for Iran-Black sheep. It appears that the rates of inbreeding (0.45% per year) in this flock of Iran-Black sheep were within the critical levels as stated by Nicholas (1989) who suggested that inbreeding rates up to 0.5% per year should be acceptable in animal breeding programs. Also, estimates of inbreeding trends in this study were in accordance with those obtained by Van Wyk *et al.* (2009) in Elsenburg Dormer sheep.

The mean inbreeding levels of animals were higher than expected under random mating (Figure 2) which was computed as the co-ancestry of the breeding animals assuming random mating (Falconer & Mackay, 1996). On the other hand, we found that the increased rate in inbreeding was higher than coancestry (0.43% vs. 0.29%) which indicated that inbreeding increases remarkably more than in a random mating circumstance in uncontrolled matings. In the assessment of diversity of the population, the rate of increase in coancestry was a more important tool than inbreeding because the increase in inbreeding was affected by non-random mating while the increase in coancestry was not (Norberg & Sørensen, 2007; Sørensen, Sørensen, & Berg, 2005).

Our estimates of individual inbreeding depression for body weight traits of Iran-Black sheep were higher than the estimates of Dorostkar *et al.* (2012) in Moghani sheep, Ghavi Hossein-Zadeh (2012) in Moghani sheep, and Ceyhan, Kaygisiz, and Sezenler (2011) in Sakiz sheep. It seems that the differences in inbreeding effects could be due to differences among breeds, alleles segregating, location, management, and diversity of the founders (MacKinnon, 2003).

In the present study, the individual inbreeding depression for ADG from birth to 3MW, 3MW to 6MW, and 6MW to YW was -0.27, 0.17, and 0.103 g, respectively (Table 6). The values for ADG from birth to 3MW were lower than reported by Ghavi Hossein-Zadeh (2013) in Moghani sheep. Similar trends were observed for all traits considered in this study. Mokhtari *et al.* (2014) reported estimates of -7 (-17) and -37(-62) g for individual (maternal) inbreeding depression for BW and 3MW in this breed. The small difference between their estimates and our findings was possibly due to data filtering by the PCI criteria in our study and also for the different data size. Gowane, Prince, and Arora (2010) stated that for every 1% increase in the inbreeding coefficient, there was -16 g change in BW for Bharat Merino sheep. Also, significant negative effects of inbreeding on body weight traits in Polish Olkuska sheep have been reported by Drobik and Martyniuk (2016). They concluded that the birth weight and body weight at the age of 8 weeks decreases by 0.0071 kg and 0.0325 kg per 1% increase in inbreeding, respectively.

In the present study, we found negative and non-significant effects of inbreeding on ADG0-3, and positive effects of inbreeding on ADG3-6 and ADG6-12 per 1% increase in inbreeding rate of Iran-Black sheep. However, the significant and negative effect of inbreeding on the post-weaning daily gains per 1% increase in inbreeding rate in Thalli sheep was reported by Hussain, Akhtar, Ali, Younas, and Javed (20 06). Norberg and Sørensen (2007) also reported negative and significant effects of inbreeding on the ADG from birth to 2 months of age due to a 10% increase in inbreeding of lambs in Danish populations of Texel, Shropshire, and Oxford Down sheep. Ghavi Hossein-Zadeh (2013) studied inbreeding depression for daily weight gains at different ages in Iranian Moghani sheep. That study found that the regression coefficients of the ADG on inbreeding of lambs for a change of 1% inbreeding for ADG from birth to weaning, ADG from weaning to 6 month weight, and ADG from 3 month weight to 9 month weight were 0.574, -0.390, -0.986 and -0.164, respectively. Prince, Sushil, Mishra, and Arora (2010) reported that the inbreeding resulted in lighter lambs at all ages and lower gain from birth up to six months of age. On the contrary, Negussie, Abegaz, and Rege (2002) showed lower effects of inbreeding on growth performance for tropical fat-tailed sheep compared to our findings. Petrovic *et al.* (2013) also reported slightly lower daily gain in outbred rams than inbred lambs. In our study, the individual regression coefficients for KR0-3, KR3-6, and KR6-12 on inbreeding of all animals for 1% increase in inbreeding were -0.008, 0.021, and 0.007, respectively.

5. Conclusions

In the present study, a steady increase in the mean inbreeding level in the flock of Iran-Black sheep was observed and the annual rate of increase in inbreeding over the years was of 0.43% per year. As a whole, an increasing trend of the PCI was found for the investigated years. A detrimental effect of inbreeding on body weight traits at different ages of this sheep breed was observed. There was a minimal change per 1% increase in inbreeding in the Kleiber ratio traits. Also, maternal inbreeding depression for the studied traits was higher than those obtained on individuals except for KR3-6 and KR6-12. However, in Iran-Black sheep, the effects of inbreeding on body weights were very much pronounced in the flock but not for ADG or Kleiber ratio traits. Therefore, a well-designed mating scheme for maintaining inbreeding at the possible minimum level, e.g., inbreeding under the random mating circumstance, should be adopted to evade accumulation of inbreeding and appearance of its disadvantageous effects on economically important traits.

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