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# Inbreeding Effects on Average Daily Gains and Kleiber Ratios in Iranian Moghani Sheep

Research Article

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## ABSTRACT

The objective of the present study was to evaluate the effects of inbreeding on average daily gains and Kleiber ratios in Moghani sheep. Traits included average daily gain from birth to 3 months (ADG1), average daily gain from birth to 6 months (ADG2), average daily gain from 3 months to 6 months (ADG3), average daily gain from 3 months to 9 months (ADG4), average daily gain from 3 months to yearling (ADG5) and corresponding Kleiber ratios (KR1, KR2, KR3, KR4 and KR5, respectively). Data and pedigree information used in this study were collected at the Breeding Station of Moghani sheep 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). There were significant regression coefficients of ADG5 and KR5 on inbreeding of all lambs for changing 1% inbreeding ($P<0.01$). Indeed, there were significant regression coefficients of ADG3 ($P<0.01$) and KR3 ($P<0.05$) on inbreeding of twin-born lambs for a change of 1% in inbreeding. In addition, there were significant regression coefficients of ADG1 ($P<0.05$) and ADG5 ($P<0.05$) on inbreeding of male lambs and significant regression coefficient of ADG2 ($P<0.05$) on inbreeding of female lambs for a change of 1% in inbreeding. Effects of inbreeding on average daily gains and Kleiber ratios in Moghani sheep was not very pronounced in the flock. Planned matings are, however, suggested to avoid accumulation of inbreeding and appearance of its deleterious effects.

KEY WORDS average daily gain, fat tailed sheep, inbreeding depression, Kleiber ratio.

## INTRODUCTION

Genetic improvement programs applied in livestock have been based on two main approaches: selection and crossbreeding. By contrast to crossbreeding, intensive selection within a single population reduces genetic diversity and increases the inbreeding rate. One definition for inbreeding is given by the mating of individuals whose relatedness is greater than the average degree of relationship existing in the population, 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).

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). 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 might 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. Measuring the effect of inbreeding on productive 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 and Thomas, 1984; Ercanbrack and Knight, 1991; Analla *et al.* 1998; Dario and Bufano, 2003; 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 might occur, as well. It is apparent that different breeds and populations, as well as different traits vary in their response to inbreeding. Some populations might show a very pronounced effect of increased inbreeding for a trait, whereas others might not demonstrate much of an effect (Negussie *et al.* 2002; Barczak *et al.* 2009).

The Moghani sheep 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 their capability to produce heavy lambs (Shodja *et al.* 2006). This breed is fat-tailed with the predominant white coat color, whereas the face, legs and feet are brown. In this breed, both sexes are polled. Moghani breed is reared in a traditional migratory system; summer in the mountainous areas and winter in plain regions. A breeding station was established in 1952 in Ardebil province of Iran, where is located in a plain area named Moghan plain in the South-west of the Caspian Sea. The area has a semi-tropical climate with a hot and relatively dry summer. Temperature varies from 1.7 to 35 ˚C and average annual rainfall ranges from 250 to 600 mm. These conditions make Moghan plain very suitable for keeping sheep during the winter and cold days. The flock is kept in a summer camp from May to October utilizing rangeland and in winter camp, during November to April, utilizing pastures. In general, the main feeding source is rangeland grass and agricultural residues but the breeding animals are supplemented with barley grain two weeks prior to the beginning of breeding season, during late pregnancy and early lactation. The breeding season starts from August and lasted to October. Lambing period ranged from January to March. After lambing, lambs are ear-tagged and weighted. Selection was primarily based on general appearance and color in this breed of sheep, but body weight at birth, weaning and at higher age were sometimes considered as criteria in selection of replacements. There was a controlled mating system, so that the identity of the sire and dam of each lamb were known. Ewe lambs and ram lambs are bred at 18 months of age. Rams are used for only one year and ewes are kept for up to 6 years depending on ewe health and reproductive performance. Male and female lambs are maintained in separate flocks from 6 months of age onwards (Ghavi Hossein-Zadeh and Ardalan, 2010). To the knowledge of the author, there were not any reports on the effects of inbreeding on Kleiber ratios. The objective of this study was to evaluate the effects of inbreeding on average daily gains and Kleiber ratios of Iranian Moghani sheep over a 19-year period from 1987 to 2005.

## MATERIALS AND METHODS

### Data and pedigree information

Data and pedigree information used in this study were collected at the breeding station of Moghani sheep from 1987 to 2005. The studied traits included: average daily gain from birth to 3 months (ADG1), average daily gain from birth to 6 months (ADG2), average daily gain from 3 months to 6 months (ADG3), average daily gain from 3 months to 9 months (ADG4), average daily gain from 3 months to yearling (ADG5) and corresponding Kleiber ratios (KR1, KR2, KR3, KR4 and KR5, respectively). Kleiber ratios were calculated as follows:

$$KR1= ADG1 / (3MW)^{0.75}$$
$$KR2= ADG2 / (6MW)^{0.75}$$
$$KR3= ADG3 / (6MW)^{0.75}$$
$$KR4= ADG4 / (9MW)^{0.75}$$
$$KR5= ADG5 / (YW)^{0.75}$$

Where, 3MW, 6MW, 9MW and YW were 3-months weight, 6-months weight, 9-months weight and yearling weight, respectively. The Kleiber ratio was suggested to be as a useful indicator of growth efficiency, as well as an indirect selection criterion for feed conversion under field conditions (Scholtz and Roux 1988). The highest values of the Kleiber ratio indicate increases in weight gain with the same metabolic weight, which means obtaining higher growth without increasing the cost for maintenance energy. Moreover, it indicates higher dilution of energy requirements for maintenance (Tedeschi *et al.* 2006).

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.

Furthermore, 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 included non-inbred animals (F=0); second and third classes contemporized inbred animals (0<F≤0.10 and F>0.10, respectively). The incidences of triplets and quadruplets were low (<0.8%), so that records from lambs born in triplet and quadruplet litters were discarded.

**Statistical analysis**

The effects of inbreeding rate on average daily gains and Kleiber ratios were analyzed using the linear mixed model (Proc Mixed) with the best fitted covariance structure of SAS (SAS, 2002). 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. In the other model of analysis, inbreeding of each animal was considered as a covariate effect. Inbreeding depression was estimated as the linear regression of average daily gains and Kleiber ratios for each animal on the individual inbreeding coefficients, using the Reg procedure of SAS.

## RESULTS AND DISCUSSION

Summary statistics for average daily gains and Kleiber ratios in different inbreeding classes of animals are shown in Tables 1 and 2, respectively. The ADG1 of animals within third class of inbreeding was significantly higher than the ADG1 of lambs belonging to the first class (P<0.05), however the differences were not significant between first and second classes. The ADG2 and ADG4 of animals within second class of inbreeding was lower significantly than those of lambs belonging to the first and third classes (P<0.05), but the difference was not significant between first and third classes. The ADG3 of animals within first class of inbreeding was significantly higher than those of lambs belonging to the second class (P<0.05), however the difference was not significant between second and third classes. On the other hand, the ADG5 of animals was not significant between three classes of inbreeding. The KR2 and KR4 of animals within second class of inbreeding was lower significantly than those of lambs belonging to the first and third classes (P<0.05), but the difference was not significant between first and third classes. The KR3 of animals within first class of inbreeding was significantly higher than those of lambs belonging to the second class (P<0.05). On the other hand, the KR1 and KR5 of animals were not significant between three classes of inbreeding. Inbreeding is generally associated with deterioration in growth and reproductive traits in small ruminants (Lamberson and Thomas, 1984; Wocac, 2003) and level of inbreeding might be an important factor for such effects to be appeared. The inbreeding coefficient is 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; however in this case the accuracy is strongly determined by the incompleteness of pedigrees (Barczak *et al.* 2009). Selvaggi *et al.* (2010) reported ewe lambs' average daily gain from birth to weaning was significantly lower in animals in the third class of inbreeding (F≥10%) compared with those of first (F=0) and second (0<F<10%) classes. Instead, no significant differences were found between ewe lambs belonging to the first and second classes. They found similar results regarding to the type of lamb (single or twin). Consistent with the result of this study, Hussain *et al.* (2006a) reported non-significant effect of inbreeding on pre-weaning daily gain in Thalli sheep.

Single or twin-born lambs showed no significant differences in their ADG5 irrespective of the inbreeding rate (Table 3). In addition, single born lambs showed no significant differences in their ADG1, and twin-born lambs showed no significant differences in their ADG2. The ADG3 and ADG4 of single-born lambs within second class of inbreeding were significantly lower than those of other classes (P<0.05). The ADG2 of single-born lambs within first class of inbreeding was significantly higher than those of lambs in the second one (P<0.05). The ADG1 of twin-born lambs within third class of inbreeding was significantly greater than those of other classes (P<0.05). The ADG3 of twin-born lambs within third class of inbreeding was significantly lower than those of the first class (P<0.05). Moreover, the ADG4 of twin-born lambs within third class of inbreeding was significantly greater than those of the second class (P<0.05).

Male or female lambs showed no significant differences in their ADG3 and ADG5 irrespective of the inbreeding rate (Table 4). Indeed, female lambs showed no significant differences in their ADG1 and ADG2. The ADG1 of male lambs within third class of inbreeding was significantly greater than those of other classes (P<0.05).

**Table 1** Average daily gains in different inbreeding classes of Iranian Moghani sheep

| Inbreeding class | Trait | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ADG1 (g) | | ADG2 (g) | | ADG3 (g) | | ADG4 (g) | | ADG5 (g) | |
| | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD |
| F= 0 | 3268 | 212±52$^{a}$ | 2506 | 169±35$^{a}$ | 2409 | 133±73$^{a}$ | 1820 | 100±65$^{a}$ | 1080 | 65±40 |
| 0 < F ≤ 0.10 | 877 | 218±55$^{ab}$ | 582 | 158±33$^{b}$ | 536 | 107±69$^{b}$ | 331 | 74±47$^{b}$ | 234 | 54±30 |
| F > 0.10 | 61 | 227±54$^{b}$ | 50 | 171±38$^{a}$ | 45 | 122±65$^{ab}$ | 39 | 115±84$^{a}$ | 20 | 63±46 |

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
ADG1: average daily gain from birth to 3 months; ADG2: average daily gain from birth to 6 months; ADG3: average daily gain from 3 months to 6 months; ADG4: average daily gain from 3 months to 9 months and ADG5: average daily gain from 3 months to yearling.

**Table 2** Kleiber ratios in different inbreeding classes of Iranian Moghani sheep

| Inbreeding class | Trait | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | KR1 | | KR2 | | KR3 | | KR4 | | KR5 | |
| | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD |
| F= 0 | 3268 | 19.92±2.19 | 2506 | 11.78±0.98$^{a}$ | 2409 | 9.10±4.46$^{a}$ | 1820 | 6.28±3.84$^{a}$ | 1080 | 3.96±2.14 |
| 0 < F ≤ 0.10 | 877 | 19.91±2.14 | 582 | 11.48±0.95$^{b}$ | 536 | 7.64±4.29$^{b}$ | 331 | 4.82±2.75$^{b}$ | 234 | 3.48±1.69 |
| F > 0.10 | 61 | 20.26±2.13 | 50 | 11.73±1.02$^{a}$ | 45 | 8.04±3.40$^{ab}$ | 39 | 6.99±4.80$^{a}$ | 20 | 3.70±2.34 |

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
KR1: Kleiber ratio from birth to 3 months; KR2: Kleiber ratio from birth to 6 months; KR3: Kleiber ratio from 3 months to 6 months; KR4: Kleiber ratio from 3 months to 9 months and KR5: Kleiber ratio from 3 months to yearling.

**Table 3** Average daily gains in different inbreeding classes of Iranian Moghani sheep grouped by the litter size

| Litter size | Inbreeding class | Trait | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ADG1 (g) | | ADG2 (g) | | ADG3 (g) | | ADG4 (g) | | ADG5 (g) | |
| | | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD |
| Single | F= 0 | 1898 | 225±49 | 1485 | 176±36$^{a}$ | 1430 | 135±79$^{a}$ | 1215 | 98±66$^{a}$ | 717 | 65±41 |
| | 0 < F ≤ 0.10 | 485 | 234±55 | 329 | 166±33$^{b}$ | 301 | 110±73$^{b}$ | 204 | 74±48$^{b}$ | 150 | 52±31 |
| | F > 0.10 | 36 | 230±60 | 30 | 184±39$^{ab}$ | 28 | 144±68$^{a}$ | 28 | 112±81$^{a}$ | 17 | 62±49 |
| Twin | F= 0 | 1342 | 1934±50$^{b}$ | 1000 | 159±33 | 958 | 131±65$^{a}$ | 593 | 103±63$^{ab}$ | 355 | 64±38 |
| | 0 < F ≤ 0.10 | 375 | 197±48$^{b}$ | 244 | 149±30 | 226 | 106±65$^{ab}$ | 124 | 75±47$^{b}$ | 81 | 57±28 |
| | F > 0.10 | 25 | 224±46$^{a}$ | 20 | 150±26 | 17 | 86±41$^{b}$ | 11 | 122±93$^{a}$ | 3 | 66±27 |

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
ADG1: average daily gain from birth to 3 months; ADG2: average daily gain from birth to 6 months; ADG3: average daily gain from 3 months to 6 months; ADG4: average daily gain from 3 months to 9 months and ADG5: average daily gain from 3 months to yearling.

**Table 4** Average daily gains in different inbreeding classes of Iranian Moghani sheep grouped by the lamb sex

| Lamb sex | Inbreeding class | Trait | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ADG1 (g) | | ADG2 (g) | | ADG3 (g) | | ADG4 (g) | | ADG5 (g) | |
| | | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD |
| Male | F= 0 | 1641 | 202±46$^{b}$ | 1235 | 157±30$^{ab}$ | 1191 | 117±63 | 879 | 95±61$^{a}$ | 461 | 70±38 |
| | 0 < F ≤ 0.10 | 459 | 205±49$^{b}$ | 296 | 150±28$^{b}$ | 273 | 98±60 | 156 | 66±41$^{b}$ | 112 | 53±26 |
| | F > 0.10 | 31 | 225±43$^{a}$ | 28 | 166±27$^{a}$ | 27 | 110±46 | 19 | 89±69$^{ab}$ | 7 | 52±16 |
| Female | F= 0 | 1627 | 223±55 | 1271 | 180±37 | 1218 | 148±80 | 941 | 104±69$^{b}$ | 619 | 61±41 |
| | 0 < F ≤ 0.10 | 418 | 229±59 | 286 | 167±36 | 263 | 117±77 | 175 | 81±52$^{b}$ | 122 | 54±33 |
| | F > 0.10 | 30 | 231±65 | 22 | 177±48 | 18 | 140±84 | 20 | 140±90$^{a}$ | 13 | 68±56 |

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
ADG1: average daily gain from birth to 3 months; ADG2: average daily gain from birth to 6 months; ADG3: average daily gain from 3 months to 6 months; ADG4: average daily gain from 3 months to 9 months and ADG5: average daily gain from 3 months to yearling.

The ADG2 of male lambs within third class of inbreeding was significantly higher than those of lambs belonging to second class (P<0.05) and the ADG4 of male lambs within first class of inbreeding was significantly higher than lambs in second class (P<0.05). Furthermore, the ADG4 of female lambs within third class of inbreeding was significantly greater than other classes (P<0.05). Single or twin-born lambs showed no significant differences in their KR5 irrespective of the inbreeding rate (Table 5). Moreover, single-born lambs showed no significant differences in their KR1 and twin born lambs demonstrated no significant differences in their KR2. The KR2 and KR3 of single born lambs within the third class of inbreeding were significantly greater than those of the second (P<0.05). However, the KR4 of single-born lambs in the second class of inbreeding was significantly lower than those of other classes (P<0.05). The KR1 of twin-born lambs in the third class was significantly greater than other classes (P<0.05). Also, the KR3 of twin-born lambs in the first class of inbreeding was significantly greater than those of the third (P<0.05).

The KR4 of twin-born lambs in the third class of inbreeding was significantly greater than those of the second one (P<0.05; Table 5). Male or female lambs showed no significant differences in their KR1, KR3 and KR5 irrespective of the inbreeding rate (Table 6). Indeed, female lambs showed no significant differences in their KR2. The KR2 of male lambs in third class of inbreeding was significantly higher than those of lambs in second class (P<0.05) and the KR4 of male lambs within first class of inbreeding was significantly higher than those of lambs belonging to second group (P<0.05). In addition, the KR4 of female lambs within third class of inbreeding was significantly greater than those of other classes (P<0.05; Table 6). The regression coefficients of average daily gains and Kleiber ratios on inbreeding of lambs for changing 1% in inbreeding are presented in Tables 7 and 8.

**Table 5** Kleiber ratios in different inbreeding classes of Iranian Moghani sheep grouped by the litter size

| Litter size | Inbreeding class | Trait | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | KR1 | | KR2 | | KR3 | | KR4 | | KR5 | |
| | | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD |
| Single | F= 0 | 1898 | 20.24±2.03 | 1485 | 11.88±1.00[ab] | 1430 | 8.89±4.61[ab] | 1215 | 6.12±3.86[a] | 717 | 3.92±2.21 |
| | 0 < F ≤ 0.10 | 485 | 20.30±2.14 | 329 | 11.61±0.99[b] | 301 | 7.48±4.41[b] | 204 | 4.70±2.78[b] | 150 | 3.33±1.78 |
| | F > 0.10 | 36 | 20.24±2.49 | 30 | 11.99±1.09[a] | 28 | 9.13±3.53[a] | 28 | 6.76±4.61[a] | 17 | 3.67±2.52 |
| Twin | F= 0 | 1342 | 19.51±2.29[b] | 1000 | 11.63±0.93 | 958 | 9.42±4.23[a] | 593 | 6.64±3.80[ab] | 355 | 4.04±2.04 |
| | 0 < F ≤ 0.10 | 375 | 19.40±2.03[b] | 244 | 11.32±0.87 | 226 | 7.88±4.18[ab] | 124 | 5.01±2.74[b] | 81 | 3.74±1.50 |
| | F > 0.10 | 25 | 20.32±1.73[a] | 20 | 11.34±0.77 | 17 | 6.25±2.32[b] | 11 | 7.57±5.45[a] | 3 | 3.89±1.09 |

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
KR1: Kleiber ratio from birth to 3 months; KR2: Kleiber ratio from birth to 6 months; KR3: Kleiber ratio from 3 months to 6 months; KR4: Kleiber ratio from 3 months to 9 months and KR5: Kleiber ratio from 3 months to yearling.

**Table 6** Kleiber ratios in different inbreeding classes of Iranian Moghani sheep grouped by the lamb sex

| Lamb sex | Inbreeding class | Trait | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | KR1 | | KR2 | | KR3 | | KR4 | | KR5 | |
| | | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD |
| Male | F= 0 | 1641 | 19.67±2.06 | 1235 | 11.55±0.92[ab] | 1191 | 8.49±4.14 | 879 | 6.26±3.79[a] | 461 | 4.29±2.04 |
| | 0 < F ≤ 0.10 | 459 | 19.55±2.04 | 296 | 11.29±0.85[b] | 273 | 7.22±3.88 | 156 | 4.48±2.49[b] | 112 | 3.50±1.50 |
| | F > 0.10 | 31 | 20.08±1.59 | 28 | 11.61±0.65[a] | 27 | 7.51±2.59 | 19 | 5.83±4.45[ab] | 7 | 3.29±0.76 |
| Female | F= 0 | 1627 | 20.19±2.24 | 1271 | 12.00±0.99 | 1218 | 9.69±4.68 | 941 | 6.31±3.88[b] | 619 | 3.72±2.19 |
| | 0 < F ≤ 0.10 | 418 | 20.25±2.18 | 286 | 11.67±1.01 | 263 | 8.08±4.64 | 175 | 5.13±2.94[b] | 122 | 3.46±1.85 |
| | F > 0.10 | 30 | 20.60±2.69 | 22 | 11.89±1.36 | 18 | 8.84±4.32 | 20 | 8.10±4.97[a] | 13 | 3.93±2.86 |

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
KR1: Kleiber ratio from birth to 3 months; KR2: Kleiber ratio from birth to 6 months; KR3: Kleiber ratio from 3 months to 6 months; KR4: Kleiber ratio from 3 months to 9 months and KR5: Kleiber ratio from 3 months to yearling.

**Table 7** Regression coefficients (±SE) of average daily gains on inbreeding of lambs for a change of 1% inbreeding

| Item | Traits | | | | |
|---|---|---|---|---|---|
| | ADG1 | ADG2 | ADG3 | ADG4 | ADG5 |
| Single | 0.23±0.493 | -0.068±0.388 | -0.168±0.878 | 0.033±0.722 | -0.248±0.609 |
| Twin | 1.138±0.599† | -0.756±0.433† | -2.192±0.929* | -0.735±1.169 | -0.137±1.043 |
| Male | 1.100±0.503* | 0.306±0.348 | -0.505±0.753 | -1.489±0.827† | -1.875±0.812* |
| Female | 0.031±0.600 | -1.067±0.449* | -1.358±1.026 | 0.993±0.887 | 0.723±0.673 |
| All | 0.574±0.399 | -0.390±0.298 | -0.986±0.644 | -0.164±0.611 | 0.052±0.0004** |

* Significant at P<0.05 and ** Significant at P<0.01.
† Trend for significance (0.05<P<0.10).
ADG1: average daily gain from birth to 3 months; ADG2: average daily gain from birth to 6 months; ADG3; average daily gain from 3 months to 6 months; ADG4: average daily gain from 3 months to 9 months and ADG5: Average daily gain from 3 months to yearling.

**Table 8** Regression coefficients (±SE) of Kleiber ratios on inbreeding of lambs for a change of 1% inbreeding

| Item | Traits | | | | |
|---|---|---|---|---|---|
| | KR1 | KR2 | KR3 | KR4 | KR5 |
| Single | 0.011±0.020 | 0.001±0.011 | -0.011±0.052 | -0.001±0.044 | -0.004±0.033 |
| Twin | 0.021±0.026 | -0.021±0.012† | -0.142±0.060* | -0.051±0.069 | -0.004±0.056 |
| Male | 0.018±0.022 | 0.003±0.011 | -0.050±0.049 | -0.092±0.052† | -0.085±0.044† |
| Female | 0.009±0.024 | 0.020±0.012 | -0.070±0.060 | 0.054±0.050 | 0.040±0.036 |
| All | 0.014±0.016 | -0.009±0.008 | -0.063±0.039 | -0.014±0.036 | -0.002±0.0004** |

* Significant at P<0.05 and ** Significant at P<0.01.
† Trend for significance (0.05<P<0.10).
KR1: Kleiber ratio from birth to 3 months; KR2: Kleiber ratio from birth to 6 months; KR3: Kleiber ratio from 3 months to 6 months; KR4: Kleiber ratio from 3 months to 9 months and KR5: Kleiber ratio from 3 months to yearling.

The regression coefficients of ADG5 and KR5 on inbreeding of all lambs for change 1% in inbreeding were estimated to be 0.052 ± 0.0004 and -0.002 ± 0.0004, respectively (P<0.01). Therefore, increasing 1% inbreeding resulted to increase and decrease of ADG5 and KR5 up to 0.052 g and 0.002, respectively. The regression coefficients of other average daily gains and Kleiber ratios on inbreeding were not significant for changing 1% inbreeding in all lambs. Considering the litter size, there were significant regression coefficients of ADG3 (-2.192±0.929; P<0.01) and KR3 (-0.142±0.060; P<0.05) on inbreeding of twin born lambs for a change of 1% inbreeding. Indeed, there were trends for significance of the regression coefficients of ADG1, ADG2 and KR2 in twin-born lambs for changing 1% inbreeding. Considering the lamb sex, there were significant regression coefficients of ADG1 (1.100±0.503; P<0.05) and ADG5 (-1.875±0.812; P<0.05) on inbreeding of male lambs and significant regression coefficient of ADG2 (-1.067±0.449; P<0.05) on inbreeding of female lambs for a change of 1% in inbreeding. On the other side, there were trends for significance of the regression coefficients of ADG4, KR4 and KR5 in male lambs for change of 1% inbreeding. Hussain *et al.* (2006b) reported significant and negative effect of inbreeding on the post-weaning daily gains per 1% increase in inbreeding rate in Thalli sheep, although the results of current study showed negative and non significant effects of inbreeding on ADG3 and ADG4, and positive and significant effect of inbreeding on ADG5 per 1% increase in inbreeding rate of Moghani sheep. Khan *et al.* (2007) reported pre-weaning daily gain had improved in inbreds, while post-weaning daily gain (P<0.01) deteriorated in Beetal goats. Norberg and Sørensen (2007) reported significant and negative effect of inbreeding on the average daily gain from birth to 2 months of age due to 10% increase in inbreeding of lamb in Danish populations of Texel, Shropshire, and Oxford Down sheep.

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, “desirable” and “undesirable” inbreeding effects are mixed (Barczak *et al.* 2009).

The results of this study showed both significant and non-significant effects of inbreeding on average daily gains or Kleiber ratios. Consistent with the current results, Barczak *et al.* (2009) reported positive inbreeding effects on growth traits in a multi-breed sheep population, although Negussie *et al.* (2002) reported lower effects of inbreeding on growth performance of tropical fat-tailed sheep. The net effect of inbreeding in a selection program is dependent on the magnitude of the selection response relative to the depression due to the accumulated inbreeding. Depending on whether genetic gain and inbreeding depression compensate for each other, the level of inbreeding might need to be accounted for in the selection process. Most breeding programs might try to minimize accumulation of inbreeding and quantify the increase by calculating the change in inbreeding per generation (Boichard *et al.* 1997) to limit the possible negative effect of inbreeding on productive and reproductive traits. Weigel (2001) reviewed multiple studies summarizing current information on control of inbreeding in livestock programs and indicated that reductions of family size and increased number of selected males and females decreased inbreeding with only small reductions in genetic gain. The results of this study showed that only < 2% of animals had inbreeding levels greater than 10%. This probably indicated the non-intensive use of few sires and application of the planned mating programs to avoid high levels of inbreeding in Iranian Moghani sheep.

## CONCLUSION

Effects of inbreeding on average daily gains and Kleiber ratios in Moghani sheep was not very pronounced in the flock. Planned matings are, however, suggested to avoid accumulation of inbreeding and appearance of its deleterious effects.

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