Inbreeding Effect On Reproductive Traits In Four Maternal Lines Of Rabbits

M. Ragab and M. Baselga

Introduction
The inbreeding is a result of the mating between relatives and increases homocigosity (Falconer, 1989). Consequently, the average of many traits, particularly the ones related with reproduction, is negatively affected and increases the probability of expression of deleterious recessive alleles. All these effects, called inbreeding depression, can be important in small, closed populations (Sewalem et al. (1999), Thompson et al. (2000)). Furthermore, an increased rate of inbreeding also means an increased risk to a breeding program in terms of the variance of genetic gain (Meuwissen (1991)), and a reduction of the additive genetic variance. The selection in finite populations has cumulated effects increasing inbreeding and reducing genetic gain (Verrier et al. (1990), Wray et al. (1990), Wray and Thompson (1990)). In rabbit, Moura et al. (2000) have estimated the reduction in litter size at birth and at weaning caused by a 10% of inbreeding of the doe: 0.81 and 0.59 young per litter respectively. In the same context, Chai (1961), Ferraz et al. (1991) and Park et al. (1991) also noted a consistent reduction in litter size at birth and at weaning as a consequence of inbreeding. The objectives of this study were to determine the current inbreeding in four maternal lines of rabbits selected for litter size at weaning and to assess the potential impact of inbreeding on litter size traits and kindling interval.

Material and methods
Animals. The present study was conducted on four Spanish maternal lines of rabbits, A, V, H and LP. These lines have been selected for a long time to increase the litter size at weaning. The analysis included the data from the 1st generation to the 38th, 34th, 15th and 4th generation in A, V, H and LP lines, respectively. All lines are kept closed since its foundation. A total of 47132 parities were considered and the pedigree file included 14609 individuals.

Selection was in non overlapping generations and the does for the next generation were selected from the best evaluated matings. It was tried to avoid the mating between close relatives and the mates could not have common grandparents. The bucks were selected within sire from the best mating of the sire, trying that each sire contributed with a son to the next generation.

Inbreeding coefficient. The inbreeding coefficient was calculated by using the recursive algorithm described by Tier (1990).

Traits and statistical analysis. The traits studied were: total born (TB), number born alive (BA), number weaned (NW, 28d), number marketed (NM, 63d) and kindling interval (number of days between two consecutive parities). The mixed models used to analyse the traits are given in the next section to estimate the inbreeding effect on the litter size traits and kindling interval. The PEST package (Groeneveld (1990)) was used to solve the models.

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Model of analysis. The traits were studied by using two-trait repeatability animal models, to estimate previously the variance-covariance components and to estimate the inbreeding effect. The litter size at weaning was included in the analysis of the other traits in order to obtain estimates unbiased by selection. Litter size at weaning was analyzed alone.

The model used for the trait t of litter size was as follows:

\[ y_{tijkmn} = FYS_i + PS_j + L_k + FYSL_{ik} + F_m + a_{nk} + p_{nk} + e_{tijkmn} \]

where, \( y_{tijkmn} \) is a record of the trait t of litter size. \( FYS_i \) is a fixed effect, farm-year-season of the parity (132 levels). \( PS_j \) is a fixed effect, physiological state of the doe (5 levels). \( L_k \) is a fixed effect, line effect (4 levels). \( FYSL_{ik} \) is a fixed effect, interaction between farm-year-season and line (291 levels). \( F_m \) is a fixed effect, the inbreeding effect (7 levels depending on the inbreeding of the doe): 1 from 0 to 0.05, 2 from 0.05 to 0.10, 3 from 0.10 to 0.15, 4 from 0.15 to 0.20, 5 from 0.20 to 0.25, 6 from 0.25 to 0.30, 7 from 0.30 to 0.35. \( a_{nk} \) is a random effect, the additive value of the doe n, nested to the line k. \( p_{nk} \) is a random effect, the permanent environmental effect of the doe n. \( e_{tijkmn} \) is a random effect, residual of the model.

Inbreeding was used as a fixed effect after sorting it into categories, as previously explained, in order to reduce the problem of its co-linearity with farm-year-seasons.

Fertility was studied by the kindling interval: number of days between two consecutives parities. The comparison between lines for kindling interval was carried out by a two-trait repeatability animal model being the other trait the litter size at weaning.

The model used for kindling interval was as follows:

\[ y_{ijkmn} = FYS_i + PO_j + L_k + FYSL_{ik} + F_m + a_{nk} + p_{nk} + e_{ijkmn} \]

where, \( y_{ijkmn} \) is a record of kindling interval, \( PO_j \) is a fixed effect, parity order of the doe (14 levels) and the other effects ( \( FYS_i, FYSL_{ik}, F_m, a_{nk}, p_{nk}, e_{ijkmn} \) ) like in the anterior paragraph.

Results and discussion

Inbreeding coefficient. The minimum, maximum and mean of the inbreeding coefficient for A, V and H lines for the last generation are shown in Table 1. The inbreeding coefficient for the animals of the LP line was equal zero because the line was still in the 4th generation of selection and any mating between relatives had still been performed.

<table>
<thead>
<tr>
<th>Lines</th>
<th>A</th>
<th>V</th>
<th>H</th>
<th>LP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>38</td>
<td>34</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.29</td>
<td>0.24</td>
<td>0.12</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.31</td>
<td>0.27</td>
<td>0.15</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td>0.30</td>
<td>0.25</td>
<td>0.14</td>
<td>0</td>
</tr>
</tbody>
</table>

These figures allow the computation of an effective population size (\( N_e \)) for each line, applying the formula, \( F_t = 1 - \{1 - 1/(2N_t)\}^t \), being \( F_t \) the inbreeding reached at the last generation, the generation t. \( N_e \) would be the effective population size. The resulting values of \( N_e \) were: 54 animals for line A, 59 animals for Line V and 47 animals for line H. We can compare these values with the expected \( N_e \) for these lines if the reproduction would have
been at random without selection and the size of these lines was intended around 25 males and 125 females. The corresponding $N_e$ would be given by the formula, $1/N_e = 1/4N_m + 1/4N_f$, where, $N_m$ and $N_f$ are the number of males and females. The result is 83, which corresponds to an increase per generation of 0.006 of the inbreeding coefficient. The actual increases have been 0.008 in the line A, 0.007 in the line V and 0.009 in the line H, all of them higher than 0.006, due to the effect of selection. Wray (1989) noted that the increase in inbreeding under selection could be several times the increase expected under random mating. In our case the effect of selection seems to be lower, probably because the management followed to reduce the increase of the inbreeding. In material and methods it was explained that each male contributed with a son to the next generation and the mating between animals sharing grandparents was avoided.

**Effect of inbreeding.** The effect of inbreeding levels on litter size traits and kindling interval are presented in Table 2.

<table>
<thead>
<tr>
<th>Inbreeding levels</th>
<th>TB</th>
<th>BA</th>
<th>NW</th>
<th>NM</th>
<th>KI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ≤ F ≤ 0.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.05 &lt; F ≥ 0.10</td>
<td>-0.06±0.11</td>
<td>-0.07±0.11</td>
<td>-0.13±0.14</td>
<td>-0.21±0.36</td>
<td>-0.91±0.49</td>
</tr>
<tr>
<td>0.10 &lt; F ≥ 0.15</td>
<td>-0.43±0.14</td>
<td>-0.49±0.14</td>
<td>-0.41±0.17</td>
<td>-0.30±0.45</td>
<td>-2.15±0.61</td>
</tr>
<tr>
<td>0.15 &lt; F ≥ 0.20</td>
<td>-0.33±0.16</td>
<td>-0.28±0.21</td>
<td>-0.28±0.21</td>
<td>-0.27±0.56</td>
<td>-1.97±0.75</td>
</tr>
<tr>
<td>0.20 &lt; F ≥ 0.25</td>
<td>-0.59±0.20</td>
<td>-0.43±0.17</td>
<td>-0.35±0.25</td>
<td>-0.33±0.64</td>
<td>-2.40±0.91</td>
</tr>
<tr>
<td>0.25 &lt; F ≥ 0.30</td>
<td>-0.40±0.22</td>
<td>-0.33±0.23</td>
<td>-0.36±0.28</td>
<td>-0.23±0.75</td>
<td>-3.23±1.03</td>
</tr>
<tr>
<td>0.30 &lt; F ≥ 0.35</td>
<td>-0.66±0.32</td>
<td>-0.69±0.32</td>
<td>-0.67±0.39</td>
<td>-0.51±1.06</td>
<td>-2.19±1.51</td>
</tr>
</tbody>
</table>

TB: Total born; BA: Number born alive; NW: litter size at weaning; NM: litter size at marketing; KI: kindling interval

The inbreeding had a negative effect on the litter size traits, named inbreeding depression. The inbreeding depression increased with increased inbreeding. At an inbreeding level from 30 to 35% the diminution in total born was 0.66 young, 0.67 in number born alive, 0.67 in number weaned and 0.51 in number marketed. The increase, in the effects, seems non linear. It appears a light effect from the first level (0 ≤ F ≥ 0.05), to the second (0.05 < F ≥ 0.10), a plateau between the third (0.10 < F ≥ 0.15) and the sixth (0.25 < F ≥ 0.30) and a new increase between the sixth and the seventh (0.30 < F ≥ 0.35).

The negative inbreeding effects lead to reduce the mean of the traits along the generations, but this reduction does not seem important and the current values of the lines show figures very high, similar o better than the values reported in Spain for commercial farms and different maternal lines (Ramón and Rafel (2002)). These lines have been selected successfully for litter size at weaning (Garcia and Baselga (2002a, b)) and the inbreeding depression has not been enough for masking the response to selection. The set of results showed in Table 2 are also indicators of low effects of the inbreeding. The inbreeding negative effects on the litter size traits are in agreement with reports by Ferraz et al. (1991) and Moura et al. (2000) in rabbit and by Falconer (1960) in mice. But their reported negative
inbreeding effects on litter size traits were higher than in our study. Moura et al. (2000) estimated the reduction in litter size at birth and at weaning caused by a 10% of inbreeding of the doe: 0.81 and 0.59 rabbits per litter, respectively. In the same context, Ferraz et al. (1991) found that the reduction of litter size at weaning can go up to 1.4 rabbits/litter, if the does and litters had an inbreeding coefficient of 0.10 and it was the 26% of the trait mean. The inbreeding negative effects on the litter size traits could be a result of reduction in milk production and general maternal ability, as suggested by Brinks and Knapp (1975).

In general, the standard errors were relatively high, particularly for the number marketed, and increased with the level of inbreeding. These high standard errors, despite the high number of records considered in the analysis are an indication that the structure of our data is no well conditioned for the estimation of this effect. One reason could be the relatively close associations between levels of inbreeding and farm-year-seasons and even more with the interaction between farm-year-season and line, which make difficult the separation between farm-year-season effects and inbreeding effects. It is relatively common that the type of data as ours have intrinsic difficulties to estimate the effect of the inbreeding and to discriminate if the apparent non linearity of the effect is real or a statistical artefact.

The estimated effects of the inbreeding on the kindling interval seem few important, being the maximum estimated effect -3.23d, that is actually low, lower than the effect that could be expected for a fertility trait. All the comments made about the estimation of the effects of the inbreeding on litter size traits apply also to the kindling interval and the overall picture seems to indicate that the effect of the inbreeding on the fertility of our lines was low.

References