GENETIC SELECTION FOR LITTER SIZE AND OVULATION RATE IN RABBITS: ESTIMATION OF GENETIC PARAMETERS, DIRECT AND CORRELATED RESPONSES

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ABSTRACT

Our objectives were to estimate direct and correlated responses in survival rates in an experiment of selection for ovulation rate and litter size in rabbits (**OR_LS line**). The experiment consisted of 2 periods of selection. In period 1, selection was performed for ovulation rate during 6 generations. In period 2, line underwent a two-stage selection for ovulation rate and litter size during 7 generations. Two-stage selection was based on the phenotypic value of ovulation rate and the average litter size over the first two parities. Total selection pressure was about 30%. The line had approximately 17 males and 75 females per generation. Traits recorded were: ovulation rate estimated as the number of corpora lutea in both ovaries (OR); number of implanted embryos (IE); litter size (LS), estimated as total number of rabbits born recorded at each parity; embryo survival (ES) estimated as IE/OR, fetal survival (FS) estimated as LS/IE, and prenatal survival (PS) estimated as LS/OR. Data were analyzed using Bayesian methodology. The estimated heritabilities of LS, OR, ES, FS and PS were 0.07, 0.21, 0.07, 0.12 and 0.16 respectively. In the first period of selection, OR increased 1.4 ova in 6 generations, but no correlated response was observed in LS due to decreased fetal survival. After 7 generations of two-stage selection for ovulation rate and litter size, OR increased 1.0 ova and correlated response on LS was high (0.9 kits). Correlated responses for embryo, fetal, and prenatal survival in the second selection period were 0.02, 0.02, and 0.07 respectively. Two-stage selection for ovulation rate and litter size could be a promising procedure to improve litter size in rabbits.

Key words: litter size, ovulation rate, survival rates, genetic responses, two-stage selection.

INTRODUCTION

Direct selection for litter size has been less successful than expected in most experiments of rabbits and pigs. Estimated responses were below 0.1 young per generation (reviewd by Mocé and Santacreu, 2010 in rabbits, Rothschild and Bidanel, 1998 in pigs). Selection for components of litter size was proposed as a mean of improving indirectly litter size.

The only experiment in which the response in LS was higher than in the experiments of direct selection for litter size was performed by Ruíz-Flores and Johnson (2001) in pigs. Responses obtained in that experiment after 8 generations of selection were higher (0.26 ± 0.07 ova and 0.33 pigs ± 0.06 per generation) than the responses observed in other experiments of selection for litter size in pigs.

In rabbits, the first experiment of two-stage selection for ovulation rate and litter size is currently being carried out at the Universitat Politècnica de València (UPV). The objective of this experiment is to test whether after selection for OR, selection on both OR and LS is successfull for increasing LS. We quantify direct and correlated responses in ovulation rate, litter size and survival rates after 6 generations of selection for ovulation rate, and 7 generations of two-stage selection for ovulation rate and litter size.

MATERIALS AND METHODS

Animals and experimental design

All experimental procedures involving animals were approved by the Universitat Politècnica de València Research Ethics Committee. Animals came from the line **OR_LS.** This line was selected during 13 generations and 2 periods of selection can be distinguished:
1. Selection for ovulation rate: from generation 0 to 6, females were selected for ovulation rate estimated by laparoscopy as the number of corpora lutea in both ovaries at day 12 of second gestation.
2. Two-stage selection for ovulation rate and litter size: from generation 7 to 13, a two-stage selection experiment was carried out. In stage one, females were selected for high ovulation rate. In stage two, selection was for the higher average litter size over the first two parities of females from stage one.

Total pressure of selection in females was about 30%. In each generation, approximately 17 males and 75 females were selected. To avoid increase of inbreeding, males were selected from the best dams within sire families. Does were mated for the first time at 18-20 weeks of age and 11-12 days after each parturition thereafter. Animals were bred at the experimental farm of the Universitat Politècnica de València. Cages were “flat-deck”, with extractable nest box with isolated plastic floor. Does were kept under a constant photoperiod of 16-h light: 8-h dark and controlled ventilation.

Traits

Ovulation rate (OR), estimated as the number of corpora lutea in both ovaries, and number of implanted embryos (IE) were measured by laparoscopy at d 12 of second gestation. Total number of kits born (LS) was recorded at birth at each parity. Embryo survival (ES) was estimated as IE/OR, fetal survival (FS) was estimated as LS/IE and prenatal survival (PS) was estimated as LS/OR. Females from all generations had a second measurement of OR, females from the 1st to the 5th generation and females from 12th and 13th generations had a second post mortem measurement of IE, and ES. Data from 969 laparoscopies and 4370 parities were analysed. The number of animals in the pedigree was 1289.

Statistical analysis

Data from 13 generations of selection were used in the analysis. A bivariate repeatability animal model was fitted in order to estimate genetic parameters and genetic trends for OR and LS. Three-trait analyses were performed to analyze survival traits. Each three-trait analysis included ovulation rate, litter size and one of the three remaining traits. Heritabilities, genetic trends and correlations with OR and LS were estimated using a trivariate repeatability animal model.

The model assumed for OR, LS and ES was (Model 1)

$$y_{ijklm} = \mu + P_k + YS_i + L_j + a_{ijkl} + p_{ijkl} + e_{ijklm} \quad (1)$$

The model for fetal and prenatal survival was (Model 2)

$$y_{ijk} = \mu + YS_i + L_j + a_{ijk} + e_{ijk} \quad (2)$$

where μ is the overall mean, P is the effect of parity (5 levels for LS, and 4 levels for OR and ES), YS is the effect of year-season (one year season every three months: 38 levels for LS, 37 levels for OR, 34 levels for ES, and 30 levels for FS and PS), L is the effect of lactation state of the doe (2 levels: 1 for lactating and 2 for not lactating does when mated), a is the additive value of the animal, p is the permanent environmental effect for ovulation rate, litter size and embryo survival, and e is the residual of the model. The model for FS and PS did neither have the parity effect nor the permanent environmental effect, because records came only from the second parity, and the year-season effect had 30 levels.

Marginal posterior distributions of all unknowns were estimated by using the Gibbs sampling algorithm. The program TM developed by Legarra *et al.* (2008) was used for all Gibbs sampling procedures. Chains of 1,000,000 samples each were used, with a burning period of 200,000. One sample each 100 for the bivariate analysis and one sample each 500 for the trivariate one was saved to avoid high correlations between consecutive samples. Convergence was tested using the Z criterion of Geweke.

RESULTS AND DISCUSSION

Genetic parameters

Features of the marginal posterior distributions of the heritabilities are summarized in Table 1. Monte Carlo standard errors were small and the Geweke test did not detect lack of convergence in any case, except for fetal survival. Heritability estimate was low for LS (0.07). This estimate is similar to those presented in the literature (Blasco *et al.* , 1996; Garreau *et al.* , 2004; Laborda *et al.*, 2011 in rabbits). Heritability estimate of OR was moderate (0.21) and closer to result reported by Blasco *et al.* (1993), with a probability of 1.00 of being higher than 0.10 ($P_{0.10}$ = 1.00; Table 1). Heritability estimate of ES was low (0.07), it was similar to the estimate reported by Laborda *et al.*(2012) but lower than the one less accurate obtained by Blasco *et al.* (1993). Heritability estimate of PS agrees with the estimates in pigs (Ruíz-Flores and Johnson, 2001; Rosendo *et al.*, 2007) and in mice (Clutter *et al.* ,1990). Few experiments have estimated the genetic parameters for fetal survival. Our result was slightly lower than the estimate published in rabbits by Laborda *et al.* (2012).

Features of the marginal posterior distributions of the genetic correlations are summarized in Table 2. The estimate of the genetic correlation between ovulation rate and litter size was positive (P = 0.92; Table 2). Laborda *et al.,* (2011) reported a genetic correlation close to zero, both estimates were imprecise. The estimated genetic correlation of OR and ES was imprecise and nothing can be said about the sign. Either estimated genetic correlations of OR with FS and PS were negative with (P = 1.00; Table 2). Litter size was positively correlated with ES, FS, and PS (P = 0.94; P = 1.00 and P = 1.00 respectively; Table 2). Estimated genetic correlations were moderate with ES and FS and high with PS. These positive correlations between LS and survival rates agree with estimates found in the literature (Argente *et al.,* 1997; Blasco *et al.,* 1993, Laborda *et al.,* 2012 in rabbits; Rosendo *et al.,* 2007 in pigs).

Table 1. Features of the marginal posterior distributions of the heritability (h^2) of litter size (LS), ovulation rate (OR), embryo survival (ES), fetal survival (FS) and prenatal survival (PS)

Traits	Mean	median	$HPD_{95\%}$	$P_{0.10}$	k
LS	0.07	0.07	0.02 0.12	0.16	0.03
OR	0.21	0.21	0.13 0.29	1.00	0.14
ES	0.07	0.07	0.02 0.12	0.19	0.03
FS	0.12	0.11	0.06 0.21	0.69	0.07
PS	0.16	0.15	0.10 0.20	0.99	0.11

$HPD_{95\%}$: high posterior density interval at 95%. $P_{0.10}$: probability of the heritability being higher than 0.10. k: limit for the interval [k, +∞) of the heritability having a probability of 95%.

Genetic trends

Figure 1 shows genetic trends for the traits analyzed. We can distinguish two periods of selection.

1. Selection for ovulation rate.

After 6 generations of selection, OR increased 1.4 ova (0.23 ova/generation) and no correlated response was observed in LS. PS showed a little decrease and no response was observed in ES. Thus, the lack of correlated response in LS could be explained by the decrease of fetal survival. These results are in agreement with the obtained by Laborda *et al.* (2011, 2012) after 10 generations of selection for OR. These authors suggested an increased of fetal mortality due to either fetal competence for space or immature oocytes. For more details see Laborda *et al.* (2012).

Table 2. Features of the marginal posterior distributions of the genetic correlation between the traits analyzed: litter size (LS), ovulation rate (OR), embryo survival (ES), fetal survival (FS) and prenatal survival (PS)

Traits	Man	median	$HPD_{95\%}$	P	k
LS, OR	0.30	0.30	-0.12 0.71	0.92^{a}	-0.05^{a}
LS, ES	0.54	0.59	-0.04 0.95	0.94^{a}	-0.04^{a}
LS, FS	0.63	0.63	0.34 0.96	1.00^{a}	0.34^{a}
LS, SP	0.85	0.86	0.77 0.91	1.00^{a}	0.78^{a}
OR, ES	-0.09	-0.09	-0.53 0.34	0.67^{b}	0.29^{b}
OR, FS	-0.53	-0.50	-0.82 -0.27	1.00^{b}	-0.30^{b}
OR, PS	-0.35	-0.35	-0.62 -0.09	0.99^{b}	-0.12^{b}

$HPD_{95\%}$: high posterior density interval at 95%; P: probability of the genetic correlation being greater than zero (superscript a), or less than zero (superscript b); k: limit for the interval ^{a} [k, +∞), ^{b} (-∞, k], having a probability of 95%.

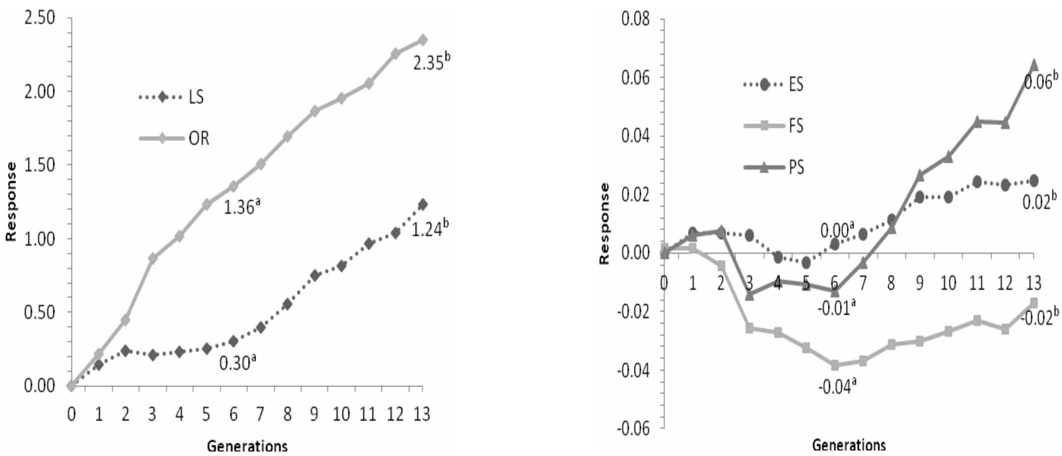

Figure 1: Genetic trends for ovulation rate (OR), litter size (LS), embryo survival (ES), fetal survival (FS) and prenatal survival (PS). Line OR_LS was selected for OR from generation 0 to 6, and for OR and LS from generation 7 to 13. Superscript a: genetic mean of the character at generation 6. Superscript b: genetic mean of the character at generation 13. [1]Unit = kits; [2]unit = ova.

2. Two-stage selection for ovulation rate and litter size:

In the second period, selection was performed for ovulation rate and litter size during 7 generations, ovulation rate increased in 1 ova (0.14 ova /generation), and litter size in approximately 0.9 kits (0.13 kit/generation). These results were lower than results obtained in pigs by Ruíz-Flores and Johnson (2001). PS increased 0.07 in 7 generations, around 1% per generation. Thus, this increase in PS and OR was responsible for the favorable response observed in LS. Little positive change in ES and FS was observed (0.02 in 7 generations).

CONCLUSION

Two-stage selection for ovulation rate and litter size seems to be more efficient to improve litter size than direct selection.

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