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Litter Survival Differences between Divergently Selected Lines for Environmental Sensitivity in Rabbits

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Simple summary: Two rabbit lines are divergently selected for increasing or decreasing the variability of litter size at birth. Decreasing litter size variability produces more resilient females with less sensitivity to diseases, being an indirect selection way for improving environmental sensitivity. Kits' survival at weaning was higher in the homogeneous line. Moreover, this line lead to greater uniformity of kits' weight at weaning, although the variability of weight at birth was higher, which could be due to a higher lactation capacity of the homogeneous line.

Abstract: A divergent selection experiment on environmental sensitivity was performed in rabbits. The aim of this study was to estimate the correlated response in kits' weight and its survival, and weight distance from birth to weaning. Weight distance was calculated as the absolute values of the differences between the individual value and the mean value of its litter. Also, relationship between probability of survival at 4 d of age and weight at birth was studied. Environmental sensitivity was measured as litter size variability. A total of 2484 kits from 127 does of the low line (selected for reducing litter size

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variability) and 1916 kits of 114 does of the high line (selected for increasing litter size variability) of the 12th generation were weighed. Bayesian methodology was used to estimate the correlated response to selection, and LOGISTIC procedure of SAS was used to estimate the relationship between weight and probability of survival. Both lines showed similar individual weight at birth and at weaning, and similar survival at birth and at 4 d of age. Survival at weaning was higher in the low line than in the high line (0.67 and 0.62; P= 0.93). Weight distance was higher at birth but lower at weaning in the low line (47.8 g and 54.1 g; P=0.98). Kit's weight at birth affected its survival. In conclusion, selection for environmental sensitivity showed correlated response in kits survival and in homogeneity of litter weight at weaning.

Keywords: correlated response; pre-weaning; survival; weight; welfare

1. Introduction

The aim of genetic selection in maternal rabbit lines has traditionally been to improve the mean of productive traits: litter size [1] or length of does' productive life [2,3]. Overall, this intensive selection for increasing productivity has had success but it has also had negative consequences on animal welfare, increasing culling at early ages [4,5]. Consequently, resistance to disease and stress are current priorities in rabbit breeding, also leading to better does resilience and welfare.

Selection for environmental sensitivity, measured as litter size variability, is an indirect selection methodology for improving resilience and robustness [6,7]. A

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divergent selection experiment for this trait has been performed with success [6], leading to lines with high and low litter size variability. Higher litter size variability affects the heterogeneity of littermates, which can produce lower pre-weaning survival [8,9]. The aim of this work is to study the correlated response in pre-weaning survival in two rabbit lines divergently selected for environmental sensitivity.

2. Material and methods

All experimental procedures involving animals were approved by the Miguel Hernández University of Elche Research Ethics Committee (Reference number 2019/VSC/PEA/0017), in accordance with Council Directives 98/58/EC and 2010/63/EU.

2.1. Animals

A divergent selection experiment for litter size variability was carried out over twelve generations. Selection was based on the phenotypic variance of litter size within the doe, after correcting litter size for both year-season and parity-lactation status [6].

All animals were reared in the farm of the Miguel Hernández University of Elche (Spain). Rabbits were fed a standard commercial diet (17% crude protein, 16% fiber, 3.5% fat, Nutricun Elite Gra ®, De Heus Nutrición Animal). Food and water were provided *ad libitum*. Does were housed in individual cages (37.5 x 33 x 90 cm) under a constant photoperiod of 16 h continuous light: 8 h continuous darkness and controlled ventilation throughout the experiment. They were first

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mated at 18 wk of age and at 10 d after parturition thereafter. Matings took place every week. The nest was made with textile by-products and the doe had free access to the nest from 2 days before delivery until 21 days after delivery, when the nest was removed. Litters were not standardised and kits were weaned at 28 days of age.

Data come from the 12th generation of selection. Litter size at birth (LS), number of born alive (NBA), number of born dead (NBD), number of rabbits at 4 days of age (N4), and number of rabbits at weaning (NW) were recorded. Rabbits were individually weighed and sexed within 24 h after birth. Some kits had suckled before being weighed. The milk intake was verified by recording a white mark in the abdominal area. Kits were also weighed at weaning. A total of 2484 kits from 127 does of the low line and 1916 kits of 114 does of the high line were weighed.

2.2. Traits

The following traits were analysed: LS; survival at birth (NBA/LS); survival at 4 days of age (N4/NBA); survival at weaning (NW/N4); individual weight at birth of live and dead kits; individual weight at weaning; weight distance of live, dead and weaned rabbits. Weight distance was calculated as the absolute values of the differences between the individual value and the mean value of its litter.

2.3. Statistical analysis

The model used for analysing LS and litter survivals were:

$$y_{ijkl} = \mu + L_i + S_j + LP_k + p_{ijkl} + e_{ijkl}$$

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where L_i is the line effect with two levels (the high and the low lines); S_j is the season effect with three levels (winter, spring and summer), LP_k is the lactation-parity effect with five levels (nulliparous, lactating and non-lactating primiparous doe, and lactating and no-lactating multiparous doe), p_{ijkl} is the dam permanent effect with 241 levels, and e_{ijkl} is the residual term.

Individual weight at birth for live and dead kits, and their correspondence distance were analysed using the following model:

$y_{ijklmnop} = LK_i + S_j + LP_k + IM_l + SE_m + p_{ijklmn} + c_{ijklmno} + b{*}LS_{ijklmno} + e_{ijklmnop}$

where LK_i is the line-survival effect (live kits of the high line, dead kits of the high line, live kits of the low line, and dead kits of the low line), IM_l is the intake of milk effect (whether the kit suckled or not before being weighed), SE_m is the sex effect (male and female), p_{ijklmn} is the dam permanent effect with 241 levels, $c_{ijklmno}$ is the common litter effect with 541 levels, b is the regression coefficient of the covariate, $LS_{ijklmno}$ is the covariate litter size and $e_{ijklmnop}$ is the residual term.

Individual weight at weaning and its distance were analysed with the same model, but line effect with two levels (high and low lines) was used instead of line-survival effect.

All analyses were performed using Bayesian methodology [10]. Bounded uniform priors were used for all effects. The joint prior distribution for the permanent environmental effect of the doe and the common litter effect was N (0, $I \otimes G_p$), where G_p was the (co)variance matrix between these effects. Residuals priori distribution was N (0, $I \otimes \sigma^2_e$). Residuals, permanent environmental effects and

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common litter effects are uncorrelated. The priors for the variances were also bounded uniform. Features of the marginal posterior distributions for all unknowns were estimated using Gibbs sampling. The program TM was used [11]. We used a chain of 250,000 samples, with a burn-in period of 50,000. Only one out of every 100 samples was saved for inferences. Convergence was tested using the Z criterion of Geweke [12] and Monte Carlo sampling errors were computed using time-series procedures [13].

The relationship between probability of survival from birth to 4 d of age and individual weight at birth was analysed by logistic regression. The model included line, season, parity-lactation (with 3 levels: nulliparous, lactating and no-lactating does), milk intake, and sex effects. Table 1 shows the number of kits that survived, classified by weight at birth and line. The LOGISTIC procedure of the statistical package SAS was used [14].

3. Results

3.1. Correlated response to selection in litter survival and preweaning weight

Table 2 shows the features of the estimated marginal posterior distributions of the differences between lines for litter survival, individual weight and weight distances at birth and weaning. Litter size at birth was higher in the low line (H-L = -0.6 kits; P = 1.0). Survival at birth and at 4 d of age were similar between lines, but survival at weaning was 5% higher in the low line (P = 0.93). Both lines showed similar individual weights of kits from birth to weaning. Weight distance for live kits at birth was higher in the low line (H-L = -0.5 g; P = 0.97); however, weight distance at weaning was lower in the low line (H-L = 6.3 g; P = 0.98).

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3.2. Survival at 4 d of age and individual weight at birth

Probability of survival at 4 d of age and weight at birth were not affected by sex. Both lines showed similar probabilities of survival at 4 d of age with the same weight at birth (Figure 1). Probabilities of survival asymptotically increased with individual birth weight, and raised more than a 90% from 60 g onwards.

Kits born in winter had less probability of survival than those born in summer or spring (Figure 2). When the weight of kits was higher than 60 g at birth, the probability of survival was maximum, no matter parity-lactation status of the doe (Figure 3). The minimum survival took place in lactating does when weights ranged from 30 to 60 g; non-lactating does showed the highest probability of survival.

Kits that suckled had always a higher probability of survival than kits that did not suckle (Figure 4). Kits with the minimum weight had a survival probability of 65% when the rabbits suckled but only 35% if they did not suckle.

4. Discussion

4.1. Correlated response to selection in litter survival and preweaning weight

Our divergent selection experiment for environmental sensitivity has showed that this trait is genetically determined [6]. This has implications for animal welfare, since animals that cope better with their environment have better welfare than more sensitive animals [7]. After correcting for litter size, both lines had similar individual weight at birth, and survival at birth and survival at 4 days of age were

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not modified. Moreover, the relationship between probability of survival at 4 d of age and the weight at birth was not affected by the line.

Weight distance has been used as dispersion measure instead of standard deviation of weight of litter because it provides one record per individual instead of one per litter. It seems that there is a correlated response on both, weight distance at birth and at weaning, but with opposite sign; the kits' weight is more variable at birth in the low line, but less variable at weaning. Up to now, there is no information about weight distance at birth in rabbits, but similar value of weight distance at weaning has been shown by Peiró *et al.* [15].

Maternal care in the first days after parturition is clearly related to the ingestion of energy by the kits, which is directly related to survival [16]. So the higher survival at weaning of the low line could indicate higher milk production and better maternal behaviour during lactation. In spite of the greater variability of weight at birth of the low line, the lactation capacity of the does produces a greater uniformity of weight at weaning than in the high line. The homogeneity in weight within litter is an important trait in prolific species like rabbits [17], because increasing weight homogeneity within the litter reduces the competition between littermates and increases the viability of them [18].

4.2. Survival at 4 d of age and individual weight at birth

Probability of individual survival at 4 d of age is related to birth weight, since the kits with lower birth weight have lower probability of survival. Neonates require a protective environment, adequate nutrition, and special maternal care, in order to

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survive [19]. So the season of birth, the intake of milk and the parity-lactation status of the doe affect the probability of survival. The probability of survival at 4 d of age was lower in winter than in spring and summer when weight at birth is less than 50 g. If birth weight is less than the optimum weight, energy reserves and thermoregulatory capacity are reduced and perinatal mortality increases [20]. If the temperature in the nest is low during their first 5 days of age, the instantaneous energy production capacity of young rabbits is insufficient to compensate for thermal losses through the skin and the probability of survival decreases [21].

Fat tissue is high at birth and decreases thereafter [22]. Ingestion of milk immediately after birth, allows the rabbit to save fat tissue and thus significantly increase its chances of survival [23,24]. The lack of milk spot at birth increases mortality of kits at 4 d of age, no matter the weight at birth. Similar results were obtained at first week of age [24,25].

When lactation and gestation were overlapping, the probability of survival was lower than in nulliparous and non-lactating does. It is well known the does undergo a nutritional deficit when lactation and pregnancy overlap [26,27] that affect the probability of kits' survival.

5. Conclusions

In conclusion, in spite of the greater variability of weight at birth of the low line, the lactation capacity of these does produced a greater uniformity of weight at

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weaning. Thus, selection for litter size variability shows a correlated response in survival and uniformity in weights at weaning, without affecting individual weight.

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Table 1. Number of kits by line effect and individual birth weight (g).

	<30	40	50	60	>70
Line H	73	316	644	494	234
Line L	128	239	756	661	338

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Table 2. Features of the marginal posterior distribution of the differences between the high and the low litter size variability lines for litter size at birth, survival, individual weight and weight distance before weaning.

	H	L	H-L	$HPD_{95\%}$	P
Litter size at birth	7.7	8.3	-0.6	-1.1; -0.2	1.0
Survival					
At birth	0.89	0.87	0.02	-0.03; 0.06	0.79
At 4 days of age	0.88	0.87	0.01	-0.04; 0.05	0.67
At weaning	0.62	0.67	-0.05	-0.12; 0.01	0.93
Individual weight					
Live at birth (g)	53.5	54.1	-0.4	-1.7; 0.8	0.75
Dead at birth (g)	46.3	46.1	-0.2	-2.4; 1.9	0.60
At weaning (g)	495	480	15	-17; 47	0.82
Weight distance					
Live at birth (g)	4.9	5.4	-0.5	-0.9; 0.0	0.97
Dead at birth (g)	7.0	6.8	0.2	-0.9; 1.3	0.68
Weaned (g)	54.1	47.8	6.3	0.2; 12.3	0.98

H = median of the high line; L = median of the low line; H-L = median of the difference between the high and the low lines; $HPD_{95\%}$ = Highest posterior density region at 95%; P = probability of the difference being >0 when H-L> 0 and probability of the difference being < 0 when H-L< 0

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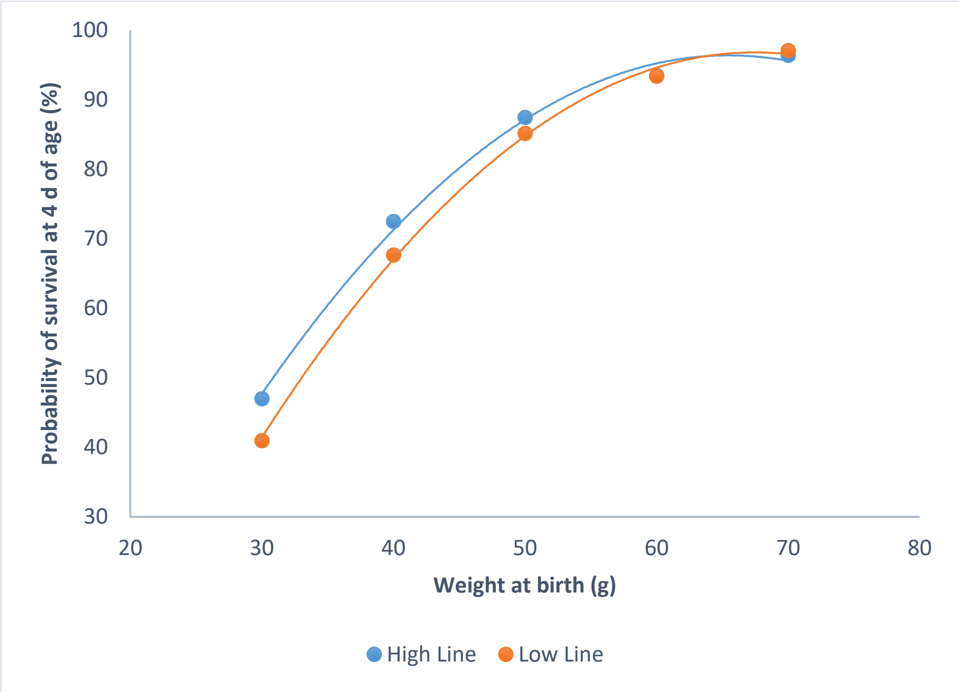

323 Figure 1. Relationship between survival at 4 d of age and individual birth weight
324 for the high and the low litter size variability lines

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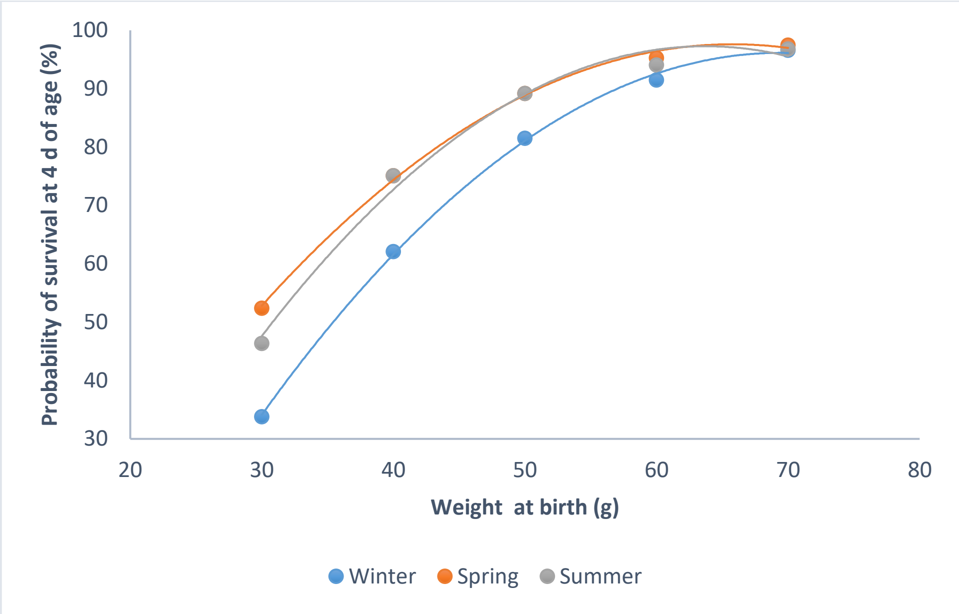

Figure 2. Relationship between survival at 4 d of age and individual birth weight for the seasons.

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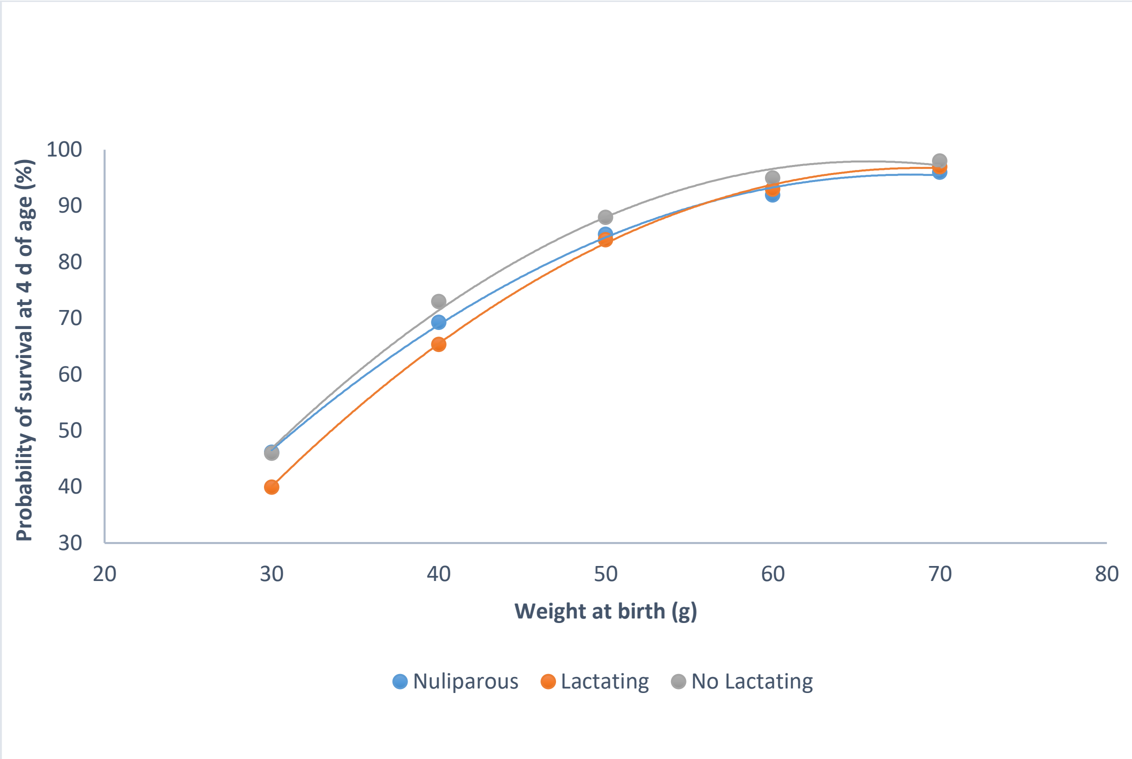

Figure 3. Relationship between survival at 4 d of age and individual birth weight for the parity-lactation status.

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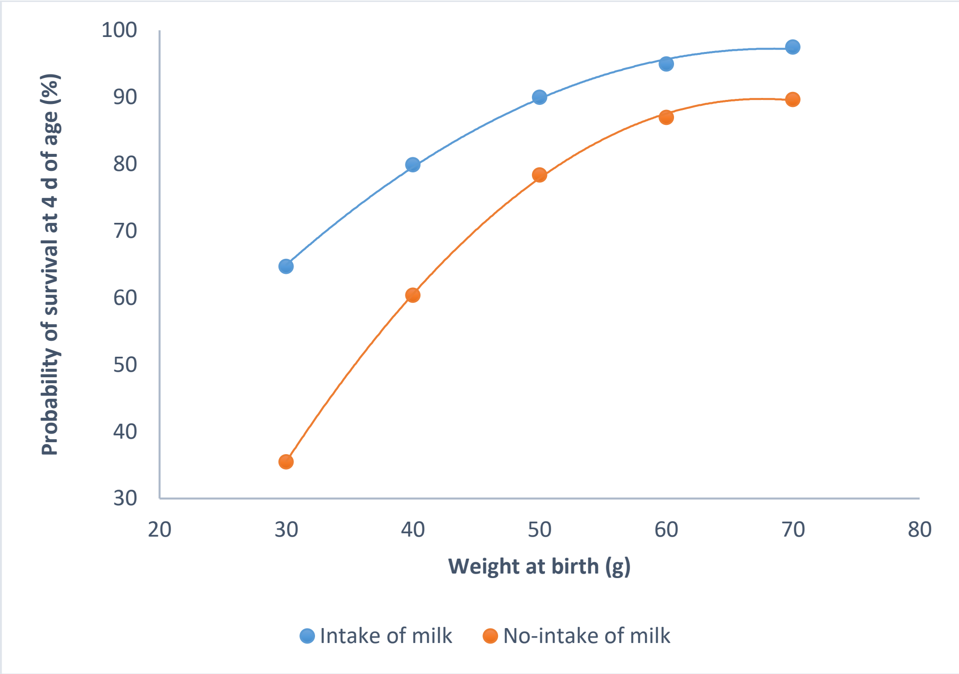
331 

332 Figure 4. Relationship between survival at 4 d of age and individual birth weight
333 for the milk intake effect.