SELECTION FOR UTERINE EFFICIENCY IN RABBITS

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Abstract - An experiment of divergent selection for uterine efficiency was performed. Rabbit does were unilaterally ovariectomized and a laparoscopy was made at mid gestation to count the number of corpora lutea in order to estimate the ovulation rate (OR) and number of implanted embryos (IE). Uterine efficiency was estimated as litter size (LS) in unilaterally ovariectomized females (ULO). Selection was performed on LS with all parities. Selection on LS was effective and a correlated response was found in IE, as well as in embryo survival. No correlated response was found in foetal survival and number of dead foetuses from implantation to birth. OR did not show a clear pattern. The LS differences found in ULO females were conserved in intact does from the High and Low selection lines.

INTRODUCTION

Selection on uterine capacity has been proposed as an indirect way to improve litter size (BENNET and LEYMASTER 1989, 1990). Uterine capacity was defined by CHRISTENSON *et al.* (1987) as the maximum number of foetuses the dam can support at birth when the number of ova shed is not a limiting factor. Uterine capacity would depend on two traits: number of implanted embryos and survival after implantation. As these traits are not necessarily related to the length or volume of the uterus, we prefer to use the expression "uterine efficiency". DZIUK (1968) and CHRISTENSON *et al.* (1987) suggested use of unilateral ovariectomy and hysterectomy to measure uterine capacity in pigs. Removing one ovary produces a duplication of the ovulation rate in the other ovary, leading to an overcrowding of embryos in the remaining uterine horn. In rabbits, unlike in pigs, transuterine migration is almost never found (BLASCO *et al.*, 1994), and BLASCO *et al.* (1994) suggested to use litter size of ovariectomized rabbit does to estimate uterine efficiency. Uterine efficiency depends on the number of implantation sites and the subsequent foetal survival. In rabbits, unlike in pigs or mice, it is possible to observe the number of corpora lutea and implantation sites by laparoscopy without damaging litter size (SANTACREU *et al.* 1990).

Only results from one selection experiment in mice have been hitherto published (KIRBY and NIELSEN, 1993), showing that uterine efficiency was not more effective than selection on litter size. However, although selection on litter size has been effective in several experiments with mice, little success has been found in closed populations of rabbits or pigs (see review by BLASCO *et al.*, 1993, 1995). The objective of this paper is to analyse the genetic responses of a divergent selection experiment on uterine efficiency in rabbits.

MATERIAL AND METHODS

Animals

The animals were derived from a synthetic population bred at the experimental farm of the Universidad Politécnica de Valencia. Each divergent line had around 40 females and 12 males per generation. The left ovary was removed before puberty. The females were mated 10 days after littering. A laparoscopy was performed in all does at the 12th day of their second gestation, and the number of corpora lutea and implanted embryos in the functional genital tract were then counted. Selection was performed on litter size, considering up to the first four parities, by using a BLUP procedure on a repeatability animal model with number of generation and parity as fixed effects. BLUP was also calculated on the High and Low lines simultaneously. Seven generations of selection were performed. Intact does from the High and Low lines were laparoscopized in the 5th, 6th and 7th generation.

Traits

For simplicity, we will use the word 'embryo' before implantation and the word 'foetus' after implantation. The following traits were analyzed: OR: ovulation rate (i.e. number of ova shed) -estimated as number of corpora lutea. IE: number of implanted embryos -estimated as number of implantation sites. LS: total number of young rabbits born PS: prenatal survival (LS/OR). ES: embryo survival (IE/OR). FS: foetal survival (LS/IE). ND: number of dead foetuses between implantation and birth (IE - LS). All the traits were measured in second parity with the exception LS, which was measured in four parities.

Surgical techniques

Ovariectomies were performed via mid-ventral incision. The does were anaesthetized using a ketamine-promethazine mixture intramuscularly injected at a rate of 1.2 ml/kg body weight; five minutes later this injection was followed by an intravenous dose of 1.5 ml of the same solution in the marginal ear vein. After grasping the ovary with haemostatic tongs, a ligation was placed around the oviduct and blood vessels and the ovary was removed. The laparoscopy technique has been described with detail by SANTACREU *et al.* (1990).

Statistical Analysis

The phenotypic differences between High and Low lines were analysed by least squares, on a model with generation and line (within generation) effects. Some of the does were lactating when they started their second gestation, thus an effect of lactation was included in the analyses. When data from several parities were analysed, parity effect was also included. Year-season effect was only included when analysing litter size, since in all other cases the data were grouped within a year-season. Procedure GLM of SAS statistical package was used (SAS, 1994).

RESULTS AND DISCUSSION

Table 1 shows the least square means and standard errors of litter size components for ULO and intact females. Unilateral ovariectomy almost duplicated the ovulation rate in the remaining ovary. The number of implanted embryos in ULO females was a 82% of the intact females. The number of dead foetuses was the same for both types of does, producing a litter size of ULO does which was an 78% of the intact females, which makes a difference with pigs (63%, CHRISTENSON *et al.*, 1987). Embryo survival was lower in ULO does, but foetal survival was almost the same (in pigs, foetal survival of intact females is substantially higher, CHRISTENSON *et al.*, 1987). BOLET *et al.* (1994) found similar results in rabbits.

Table 1 : Number of data (N), least square means (LSM), and standard error (SE) of litter size components of ULO and Intact females.

	ULO			INTACT			
	N	LSM	SE	N	M	SE	Sig.
LS	1990	7.57	0.09	542	9.75	0.14	**
OR	523	13.89	0.16	115	14.66	0.27	**
IE	523	10.44	0.16	115	12.77	0.32	**
ND	477	3.21	0.15	98	3.18	0.29	ns
ES	523	0.76	0.01	115	0.87	0.02	**
FS	477	0.71	0.01	98	0.76	0.02	*
PS	477	0.54	0.01	98	0.67	0.02	**

Table 2 shows the differences between High and Low lines in ULO females. A constant positive difference on litter size was maintained across all the generations, but no linear improvement was observed. This pattern was similar to the pattern observed for the number of implanted embryos. The rest of the traits did not show any clear pattern. Table 3 shows the same data for intact females of the High and Low lines. The litter size differences found in ULO females are conserved in intact females. Because of the small sample size for litter size components, it is difficult to assess the causes of the difference in litter size observed, but it still seems to be associated to an increment in the number of implanted embryos.

Table 2 : Differences between High and Low lines in ULO females. Gi: Generation i

	LS	OR	IE	ND	ES	FS	PS
G1	1.34**	-0.47	1.68**	-0.15	0.14**	0.02	0.13**
G2	0.77**	1.04*	0.97	-0.05	0.01	0.02	0.01
G3	0.98**	1.10+	1.71*	-0.30	0.05	0.08+	0.07
G4	1.30**	-0.89*	0.79	-1.52*	0.09*	0.16**	0.16**
G5	0.46	0.41	0.45	0.14	0.02	0.08	0.02
G6	0.25	0.20	-0.46	-0.53	-0.04	0.04	-0.01
G7	1.09**	-0.05	1.99*	0.75	0.16**	0.001	0.10

Table 3 : Differences between High and Low lines in Intact females

LS	OR	IE	ND	ES	FS	PS
1.21**	0.88	1.13	-0.71	0.03	0.09	0.10+

LS: litter size. OR: ovulation rate. IE: number of implanted embryo. ND: number of dead foetuses between implantation and birth. ES: embryo survival. FS: foetal survival. PS: prenatal survival.
**: P<0.01, *:P<0.05, +: P<0.10

Uterine capacity, measured as number of pups born to unilaterally ovariectomized females, has been effective in changing litter size in mice (KIRBY and NIELSEN, 1993), although not more effective than direct selection for LS. It has been maintained that embryo survival depend more on the embryo than on the mother, but foetal survival is more dependent on the uterus environment (see WRATHALL, 1971 and BLASCO *et al.*, 1993 for reviews). However, when the concept of uterine capacity was first proposed by BAZER *et al.* (1969), it was thought that it was the competence for some uterine factor affecting embryo survival and implantation the main cause for uterine efficiency. The model proposed by BENNET and LEYMASTER (1989, 1990) takes into account both causes, but it does not fix the implantation as the critical point to attribute the survival to the mother or the embryo. We used here LS as a measure of uterine efficiency, which includes the possible competence among embryos for some uterine factors, before and after implantation.

Selection on uterine efficiency lead to differences between lines for LS, but they were associated to an increase in the number of implanted embryos more than to an improvement of FS. The same phenomenon is observed when comparing ULO and Intact females, thus it seems that differences in LS are associated to competence among embryos before implantation, rather than after implantation. ADAMS. (1962) and HAFEZ (1964) suggested that competence among embryos could produce differences in foetal survival when the rate of implanted embryos is high. However, from our results it seems that, within the limits of our experiment, this competence is not a main factor in determining LS. The reason could be due an insufficient number of embryos implanted in the uterine horn, which is indicated by the positive correlation between IE and LS (BOLET *et al.*, 1995), but a higher rate of implantation does not seem to be possible by unilateral ovariectomy, because the correlation between OR and IE was null (BOLET at al., 1995). Moreover, in a French selection experiment of INRA, SANTACREU *et al.* (1994) showed that divergent selection on ND (a trait highly correlated with FS) in ULO females did not lead to any divergence between High and Low lines.

The improvement in number of implanted embryos can be due to differences in rate of fecundation, embryo survival or factors related to the uterus. Fecundation rate seems to be very high in intact rabbits (95-98%, ADAMS., 1960), though varying between strains (82-93%, BOLET and THEAU-CLEMENT, 1994). There are not differences in fecundation rate between intact and High or Low lines (SANTACREU *et al.*, 1996), therefore the differences in IE shall be at least attributed to differences in embryo viability or differences in uterus environment. Embryo survival depends on the embryo (vgr. chromosomic abnormalities, embryo development, etc.), but it could also depend on the uterus environment, i.e. the amount and composition of uterine secretions (BAZER *et al.*, 1990, in pigs). Chromosomic abnormalities are the responsible of around a 5% of embryo mortality in rabbits (FECHNEIMER and BEATTY, 1974). Besides, a higher uniformity in embryo development has been found sometimes in hyperprolific pigs in comparison with European breeds (BAZER *et al.*, 1988). SANTACREU *et al.* (1996) found a higher uniformity in early embryo development in the High line.

One of the major hypothesis of this experiment is that uterine efficiency in one horn is a good estimation of the whole uterine efficiency. Table 3 shows that the litter size differences found in ULO females are conserved in intact females. Selection on uterine efficiency seems thus to be possible, and it could be an alternative to direct selection for litter size in rabbits.

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