

Estimation of Genetic Parameters for Reproductive Traits between First and Later Parities in Pig

S. H. Oh, D. H. Lee* and M. T. See

North Carolina State University, Raleigh, NC, USA

ABSTRACT : The objective of this study was to estimate genetic parameters between first and later parities as different traits in reproductive traits of pigs using multiple trait animal model procedures. Data related to reproductive traits from a total of 2,371 individuals maintained at a farm were taken from the pedigree file. Sires and dams were consisted of Duroc, Landrace, and Yorkshire breeds, respectively. The first and later parity records were considered as different traits. Traits included in analyses were total pigs born (TB1), number of pigs born alive (NBA1), number of pigs weaned (NW1), and litter weaning weight (LWT1) in the first parity, and total pigs born (TB2), number of pigs born alive (NBA2), number of pigs weaned (NW2), litter weaning weight (LWT2) and interval between farrowing events (FTF) in later parities. Heritability estimates of TB1, NBA1, NW1 and LWT1 in the first parity were 0.27, 0.25, 0.16 and 0.20, respectively. For TB2, NBA2, NW2, LWT2 and FTF in later parities, heritabilities were estimated as 0.15, 0.15, 0.08, 0.11 and 0.07, respectively. Genetic correlations between sow reproductive traits in the first parity and in the second and later parity were estimated to be 0.89, 0.77, 0.58 and 0.66, respectively, between TB1 and TB2, NBA1 and NBA2, NW1 and NW2, and LWT1 and LWT2. While phenotypic correlations between TB1 and TB2, NBA1 and NBA2, NW1 and NW2, and LWT1 and LWT2 were estimated as 0.18, 0.15, 0.06 and 0.10, respectively. Genetic correlations between reproductive traits of first and later parities were not high indicating that reproductive traits for sows should be analyzed while considering the parities as different traits. (*Asian-Aust. J. Anim. Sci.* 2006. Vol 19, No. 1 : 7-12)

Key Words : Pig, Reproductive Traits, Parities, Genetic Parameters

INTRODUCTION

Improvement of productive traits in pigs is a very important issue from the viewpoint of profit to producers. However, the improvement of productive traits ignoring reproductive traits causes poor genetic progress (Rydmer et al., 1995). Because of the negative genetic correlations between many production and reproduction traits a selection index considering both should be used to improve populations. Genetic evaluation and parameter estimation for reproductive traits could be biased due to differences in parity among females (Roehe and Kennedy, 1995). It has been suggested that for genetic analyses each parity should be considered as different traits (Rothschild et al., 1979; Roehe and Kennedy, 1995).

Gilt and sow records should be considered as a separate reproductive traits because the physiological development of reproductive organs differs with the parity. If repeatability is high, that is, the correlations between parities are high, then it would be desirable to consider all parities as a single trait. However, if repeatability is low it is appropriate to analyze records on different parities as independent traits. This will make the analyses more accurate and computationally faster. Multiple trait analyses

including first and later parities as different traits have been used in Canada for pigs (Irgang et al., 1994; Roehe and Kennedy, 1995) and cattle (Reents et al., 1995). Few study on genetic variation for reproductive traits on swine populations in Korea were reported even those on productive traits were reported (Kim et al., 2003).

The objective of this study was to estimate genetic parameters between the first and later parities as different traits in analyzing reproductive traits of pigs using the multiple traits animal models.

MATERIALS AND METHODS

Data description

Data related to reproductive traits on a total of 2,371 individuals maintained at a farm in South Korea were taken from the pedigree file. Sire and dam were consisted of three breeds, respectively (Table 1). The first and later records were considered as two different traits when analyzing data. The traits included in the analyses were total pigs born (TB1), number of pigs born alive (NBA1), number of pigs weaned (NW1), and litter weaning weight (LWT1) in the first parity, and total pigs born (TB2), number of pigs born alive (NBA2), number of pigs weaned (NW2), litter weaning weight (LWT2) and interval between farrowing events (FTF) in later parities.

Age at farrowing in months was calculated as a division of days from birth to farrowing date by 30.45, and days to return to estrus was calculated as days from farrowing to the

* Corresponding Author: D. H. Lee. Dept. of Animal Life and Resources, Hankyong National University, Seokjeong-Dong 67, Anseong City, Gyeonggi-Do, 456-749, Korea. Tel: +82-31-670-5091, Fax: +82-31-676-5091, E-mail: dhlee@hknu.ac.kr
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Table 1. Number of records and percentage by breeds of sires and dams for study on a swine farm in Korea

Dam breed	Number	%	Sire breed	Number	%
Duroc	227	4.93	Duroc	227	4.93
Landrace	432	9.38	Landrace	1141	24.77
Yorkshire	3947	85.69	Yorkshire	3238	70.3

Table 2. Number of records and percentage by year-season and parity for study on a swine farm in Korea

Year-season	Records (n)	%	Parity	Records (n)	%
1998 winter	47	1.02	1	921	20.00
1999 spring	168	3.65	2	863	18.74
1999 summer	191	4.15	3	723	15.70
1999 fall	204	4.43	4	591	12.83
1999 winter	283	6.14	5	468	10.16
2000 spring	234	5.08	6	368	7.99
2000 summer	255	5.54	7	267	5.80
2000 fall	239	5.19	8	182	3.95
2000 winter	241	5.23	9	123	2.67
2001 spring	230	4.99	10	81	1.76
2001 summer	256	5.56	11	19	0.41
2001 fall	220	4.78			
2001 winter	220	4.78			
2002 spring	237	5.15			
2002 summer	207	4.49			
2002 fall	259	5.62			
2002 winter	236	5.12			
2003 spring	223	4.84			
2003 summer	215	4.67			
2003 fall	202	4.39			
2003 winter	239	5.19			

last breeding date. Days to weaning was defined as days from farrowing to weaning date, and FTF was defined as days from previous farrowing to present farrowing date. Records from which the number of fostered individuals was greater than total number of born alive or the number of weaned individuals was greater than the number of fostered individuals were eliminated. Records from which total numbers of born alive were less than two or days to weaning were less than five were also removed from the

analyses. Number of records by each parity and year-season group are shown in Table 2.

Statistical analysis

Basic statistics including the number of records, mean, standard deviation and coefficient of variation for each trait were analyzed using SAS 8.2 (Cary, NC). Two different nine-trait animal models were used to estimate genetic parameters.

The model for first parity records included year-season, dam breed, sire breed, farrowing month and days to weaning as fixed effects, and the random genetic effect of animal. The model for later parity records included fixed effects of year-season, parity, dam breed, sire breed, days from weaning to estrus and days to weaning, and random genetic effect of animal and a random permanent environmental effect. Fixed and random effects included in each model are summarized by trait in Table 3.

The vector presentation of this model is:

$$y_i = X_i b_i + Z_{ai} a_i + Z_{pi} p_i + e_i$$

where, y_i is the vector of observations for the i th trait, b_i is a vector of fixed effects for the i th trait, a_i and p_i are vectors of unknown additive genetic and permanent environmental effects for the i th trait, e_i is a vector of residuals for the i th trait and X_i , Z_{ai} and Z_{pi} are incidence matrices relating observations to the fixed, additive genetic and permanent environmental effects for the i th trait.

Fixed and random effects corresponding to traits according to first and later parity were considered as shown in Table 3.

Table 3. Fixed and random effects considered on statistical model by traits in a swine population

Trait	Fixed effect							Random effect	
	YS	PA	DAM	SIRE	FM	WTE	WD	Animal	PE
First parity									
TB1		-	○	○	○	-	-	○	-
NBA1	○	-	○	○	○	-	-	○	-
NW1	○	-	○	○	○	-	○	○	-
LWT1	○	-	○	○	○	-	○	○	-
Later parities									
TB2	○	○	○	○	-	○	-	○	○
NBA2	○	○	○	○	-	○	-	○	○
LW2	○	○	○	○	-	○	○	○	○
LWT2	○	○	○	○	-	○	○	○	○
FTF	○	○	○	○	-	○	○	○	○

YS = Year-season; PA = Parity; DAM = Breed of dam; SIRE = Breed of sire, FM = Farrowing month;

WTE = days from weaning to estrus; WD = days to weaning; PE: Permanent environment effect.

Table 4. Summary statistics for reproductive traits by first and later parities in a swine population

	N	Mean	Min	Max	SD	CV
TB1	921	11.22	3	19	2.11	18.78
NBA1	921	10.55	3	17	1.99	18.83
NW1	921	9.08	2	13	1.70	18.69
LWT1	859	57.73	6	102	13.60	23.56
TB2	3,685	12.50	5	22	2.33	18.64
NBA2	3,685	11.65	4	22	2.08	17.84
NW2	3,685	9.35	2	14	1.55	16.60
LWT2	3,049	63.95	15	105	12.42	19.42
FTF	3,685	149.37	121	350	23.99	16.06

TB1: total pigs born at the first parity; NBA1: number of pigs born alive at the first parity; NW1: number of pigs weaned at the first parity.

LWT1: litter weaning weight at the first parity; TB2: total pigs born at later parities; NBA2: number of pigs born alive at later parities.

NW2: number of pigs weaned at later parities; LWT2: litter weaning weight at later parities; FTF: interval between farrowing events at later parities.

Table 5. Genetic variances (diagonal) and covariances (below diagonal) for reproductive traits on first and later parities in a swine population

	TB1	NBA1	NW1	LWT1	TB2	NBA2	NW2	LWT2	FTF
TB1	1.204								
NBA1	1.001	0.927							
NW1	0.565	0.546	0.438						
LWT1	3.739	3.923	3.061	29.95					
TB2	0.882	0.652	0.370	1.949	0.820				
NBA2	0.758	0.582	0.308	1.792	0.683	0.616			
NW2	0.199	0.182	0.156	1.561	0.134	0.094	0.167		
LWT2	0.847	1.098	1.033	13.89	0.219	0.063	1.368	14.63	
FTF	0.277	0.113	0.911	1.386	1.165	0.593	0.505	6.437	37.00

TB1: total pigs born at the first parity; NBA1: number of pigs born alive at the first parity; NW1: number of pigs weaned at the first parity.

LWT1: litter weaning weight at the first parity; TB2: total pigs born at later parities; NBA2: number of pigs born alive at later parities.

NW2: number of pigs weaned at later parities; LWT2: litter weaning weight at later parities; FTF: interval between farrowing events at later parities.

Variance components were estimated using REML algorithm (Patterson and Thompson, 1971) and REML software package (REMLF90; Misztal, 2001) was used. Heritability and genetic correlation estimates for traits considered were calculated using estimated variance and covariance components.

RESULTS AND DISCUSSION

Basic statistics

The number of records, mean, standard deviation and coefficient of variation for each trait are summarized in Table 4. Means of TB, NBA, NW and LWT increased from first parity to later parities, that is, 11.22 to 12.50, 10.55 to 11.65, 9.08 to 9.35, and 57.73 to 63.95, respectively. Coefficient of variation for TB, NBA, NW, and LWT from first parity to later parities decreased from 18.78 to 18.64, 18.83 to 17.84, 18.69 to 16.60, and 23.56 to 19.42, respectively. This indicates that reproductive performance of sows in the population was improved after the first parity, and that variation of individuals was decreased due to selection.

Heritability estimates

Estimates of genetic, permanent environmental and error (co)variances are shown in Tables 5, 6 and 7,

respectively. Elements of covariances in the error variance matrix between traits of the first and later parities were restricted to zero because the environmental effects by parities were assumed not to be related. Permanent environmental variance components were estimated only for traits of later parities when repeated records were included.

Heritability estimates for each trait are shown in Table 8. Heritability estimates of TB1, NBA1, NW1 and LWT1 in the first parity were 0.27, 0.25, 0.16 and 0.20, respectively. For TB2, NBA2, NW2, LWT2 and FTF in later parities, heritabilities were estimated as 0.15, 0.15, 0.08, 0.11 and 0.07, respectively. These results indicate that heritability estimates for first parity traits were higher than for later parity traits. This may be due in part to the inclusion of the permanent environmental effect in the model fitted for later parities.

Heritability estimates of TB1, NBA1, NW1 and LWT1 in this study were slightly higher than those previously reported (Irgang et al., 1994; Roehe and Kennedy, 1995; Adamec and Johnson, 1996; ten Napel et al., 1998). This difference may be due to the inclusion of maternal effects in previous studies.

The heritability estimate for NBA1 in this study was higher and the heritability estimate for NBA2 was similar to those reported by Rydhmer et al. (1995) and Holm et al.

Table 6. Environmental variances (diagonal) and covariances (below diagonal) for reproductive traits on first and later parities in a swine population

	TB1	NBA1	NW1	LWT1	TB2	NBA2	NW2	LWT2	FTF
TB1	3.208								
NBA1	2.498	2.746							
NW1	1.156	1.359	2.301						
LWT1	5.942	7.384	13.69	122.4					
TB2	0.000	0.000	0.000	0.000	3.845				
NBA2	0.000	0.000	0.000	0.000	2.858	3.115			
NW2	0.000	0.000	0.000	0.000	0.607	0.741	1.654		
LWT2	0.000	0.000	0.000	0.000	2.915	3.942	10.59	103.2	
FTF	0.000	0.000	0.000	0.000	3.043	2.733	0.535	1.565	315.8

TB1: total pigs born at the first parity; NBA1: number of pigs born alive at the first parity; NW1: number of pigs weaned at the first parity.

LWT1: litter weaning weight at the first parity; TB2: total pigs born at later parities; NBA2: number of pigs born alive at later parities.

NW2: number of pigs weaned at later parities; LWT2: litter weaning weight at later parities; FTF: interval between farrowing events at later parities.

Table 7. Permanent environmental variances (diagonal) and covariances (below diagonal) for reproductive traits on later parities in a swine population

	TB2	NBA2	NW2	LWT2	FTF
TB2	0.646				
NBA2	0.524	0.491			
NW2	0.170	0.229	0.343		
LWT2	1.432	1.821	2.108	16.29	
FTF	-0.844	-0.532	-0.706	-6.549	178.5

TB1: total pigs born at the first parity; NBA1: number of pigs born alive at the first parity; NW1: number of pigs weaned at the first parity; LWT1: litter weaning weight at the first parity; TB2: total pigs born at later parities; NBA2: number of pigs born alive at later parities; NW2: number of pigs weaned at later parities; LWT2: litter weaning weight at later parities; FTF: interval between farrowing events at later parities.

(2005). However, the estimated heritability of NBA as 0.26 from a study that evaluated relationships between rebreeding and reproductive performance without separating parities was similar to the heritability of NBA1 estimated in this study (ten Napel et al., 1998). The analysis model used by Hermisch et al. (2000) included only animal as a random effect, and reported lower heritability estimates for NBA of 0.08, 0.09, and 0.08 in the first, second and third parity as a different trait, and of LWT as 0.07 in the

first parity. In another study where the model included maternal and permanent effects (Chen et al., 2003) low heritability estimates of 0.08 to 0.10 for NBA, 0.07 to 0.09 for LWT, and 0.02 to 0.06 for NW with Yorkshire, Duroc, Hampshire, and Landrace swine were reported. The low heritability of farrowing interval was in accordance with the result of Rydhmer et al. (2005) although it was limited to the interval between first and second farrowing.

Genetic and phenotypic correlations

Genotypic and phenotypic correlations are summarized in Table 8. Genetic correlations between sow reproductive traits in the first parity and in the second and later parity were estimated as 0.89, 0.77, 0.58 and 0.66 between TB1 and TB2, NBA1 and NBA2, NW1 and NW2, and LWT1 and LWT2, respectively. Phenotypic correlations between TB1 and TB2, NBA1 and NBA2, NW1 and NW2, and LWT1 and LWT2 were estimated as 0.18, 0.15, 0.06 and 0.10, respectively. Rydhmer et al. (1995) reported a similar genetic correlation (0.77) between NBA in first and later parities.

Genetic correlations between reproductive traits within the first parity were estimated as 0.95, 0.78 and 0.62

Table 8. Heritabilities (diagonal), genetic (below diagonal) and phenotypic (above diagonal) correlations for reproductive traits on first and later parities in a swine population

	TB1	NBA1	NW1	LWT1	TB2	NBA2	NW2	LWT2	FTF
TB1	0.27	0.86	0.48	0.38	-	-	-	-	-
NBA1	0.95	0.25	0.59	0.51	-	-	-	-	-
NW1	0.78	0.86	0.16	0.80	-	-	-	-	-
LWT1	0.62	0.74	0.85	0.20	-	-	-	-	-
TB2	0.89	0.75	0.62	0.39	0.15	0.85	0.29	0.20	0.01 ^{ns}
NBA2	0.88	0.77	0.59	0.42	0.96	0.15	0.38	0.29	0.03 ^{ns}
NW2	0.44	0.46	0.58	0.70	0.36	0.29	0.08	0.81	-0.01 ^{ns}
LWT2	0.20	0.30	0.41	0.66	0.06	0.02	0.87	0.11	-0.01 ^{ns}
FTF	0.04	0.02	0.23	0.04	0.21	0.12	0.20	0.28	0.07

* ns = not significant.

TB1: total pigs born at the first parity; NBA1: number of pigs born alive at the first parity; NW1: number of pigs weaned at the first parity.

LWT1: litter weaning weight at the first parity; TB2: total pigs born at later parities; NBA2: number of pigs born alive at later parities.

NW2: number of pigs weaned at later parities; LWT2: litter weaning weight at later parities; FTF: interval between farrowing events at later parities.

Table 9. Statistics for breeding value estimates of reproductive traits on first and later parities in a swine population

	TB1	NBA1	NW1	LWT1	TB2	NBA2	NW2	LWT2	FTF
Mean	-0.062	-0.060	-0.045	-0.383	-0.045	-0.039	-0.009	-0.064	-0.059
SD	0.535	0.465	0.308	2.683	0.429	0.370	0.203	1.888	2.104
Max	2.277	1.849	0.954	10.17	1.974	1.813	0.884	6.971	10.97
Upper 1%	1.329	1.060	0.657	5.938	1.181	1.036	0.529	4.984	6.242
Upper 5%	0.806	0.658	0.430	3.793	0.667	0.570	0.329	3.136	3.760
Upper 10%	0.551	0.473	0.305	2.690	0.458	0.379	0.243	2.228	2.562
Upper 25%	0.223	0.197	0.134	1.156	0.171	0.150	0.100	0.928	0.795
Median	-0.017	-0.013	-0.006	-0.043	-0.027	-0.022	0.002	0.013	-0.125
Lower 25%	-0.374	-0.321	-0.219	-1.875	-0.289	-0.245	-0.127	-1.085	-1.174
Lower 10%	-0.752	-0.664	-0.444	-3.792	-0.591	-0.510	-0.264	-2.412	-2.551
Lower 5%	-0.959	-0.855	-0.592	-5.042	-0.748	-0.646	-0.354	-3.261	-3.429
Lower 1%	-1.455	-1.294	-0.916	-7.890	-1.074	-0.944	-0.517	-4.997	-4.923
Min	-2.848	-2.487	-1.755	-14.593	-2.059	-1.720	-0.814	-7.883	-7.053

TB1: total pigs born at the first parity; NBA1: number of pigs born alive at the first parity; NW1: number of pigs weaned at the first parity.

LWT1: litter weaning weight at the first parity; TB2: total pigs born at later parities; NBA2: number of pigs born alive at later parities.

NW2: number of pigs weaned at later parities; LWT2: litter weaning weight at later parities; FTF: interval between farrowing events at later parities.

between TB1 and NBA1, TB1 and NW1, and TB1 and LWT1, respectively. Estimates of genetic correlations between NBA1 and NW1, and NBA1 and LWT1 were 0.86 and 0.74, respectively. The genetic correlation between NBA1 and LWT1 was slightly higher than that reported by Kaplan et al. (0.68; 1991). Estimates of genetic correlations between reproductive traits for later parities were 0.96, 0.36 and 0.06 between TB2 and NBA2, TB2 and NW2, and TB2 and LWT2, respectively. Estimates of genetic correlations between NBA2 and NW2, NBA2 and LWT2, and NW2 and LWT2 were 0.26, 0.02, and 0.87, respectively. These results indicate that genetic correlations between traits in later parities tended to be lower than those observed among traits in the first parity. Hermes et al. (2000) reported estimates of genetic correlations between NBA in the first, second and third parity of 0.62, 0.61, and 0.95 between the first and second, the first and third, and the second and third parities, respectively. Also, estimates of the genetic correlation between NBA and LWT for the first, second and third parities were -0.14, -0.15, and -0.75, respectively. Genetic correlations between NBA, LWT and NW have been reported that ranged from 0.10 to 0.15 between NBA and LWT, 0.07 to 0.20 between NBA and NW, and 0.65 to 0.75 between NW and LWT with Yorkshire, Duroc, Hampshire and Landrace breeds (Chen et al., 2003).

Genetic correlations between FTF and other reproductive traits were found to be higher in later parities than in the first parity. Estimates of genetic correlations between FTF and the first parity traits TB1, NBA1, NW1 and LWT1 were 0.04, 0.02, 0.23 and 0.04, respectively. Estimates of genetic correlations between FTF and later parity traits TB2, NBA2, NW2 and LWT2 were 0.21, 0.12, 0.20, and 0.28, respectively. Steverink et al. (1999) reported that litter size is greatest when rebreeding interval is 2 to 3 days and will decline until 7 days, and increase with intervals greater than 11 days. This non linear relationship

supports a low genetic correlation between FTF and traits related to litter size in this study. Current selection in these populations is based on a sow productivity index that includes only litter size and litter weight. Including rebreeding variables would be more comprehensive and these results indicate that first and later parities should be considered as different traits.

Conceptually, it is easy to think that genetic correlations between traits of the first and later parities in sows would be one, however, the results of this study indicate that these genetic correlations are not high enough to consider first and later parity records as one trait. Generally the first three parities have high genetic correlations (Haley et al., 1988), but the genetic correlation between the first and the fourth and greater parities could be lower due to the effects of selection or environment (Roehe and Kennedy, 1995). In other words, it is suitable that traits in the first parity and in later parities should be considered as different traits due to the effect of selection, permanent environment, and previous parities affecting the subsequent parities of sows.

Estimates of phenotypic correlations were higher between traits in the first parity than in later parities, and those between traits in the first parity and traits in later parities were zero due to the characteristic of data structure.

Breeding values

Statistics of breeding values for each reproductive trait from the nine-multiple traits analyses are presented in Table 9. Means of estimated breeding values of reproductive traits in the first parity were, respectively, -0.062, -0.060, -0.045 and -0.383 for TB1, NBA1, NW1 and LWT1. In later parities, means of estimated breeding values were, respectively, -0.045, -0.039, -0.009 and -0.064 for TB2, NBA2, NW2 and LWT2. In the mean time, the standard deviations of breeding values had a trend to decrease in the second and later parity rather than in the first parity.

For breeding values, estimates of later parities were higher than for first parity in all traits. Also, standard deviations of breeding values in later parities were less than in the first parity. This is in agreement with the heritability estimates of later parities being less than those for the first parity as shown in Table 8.

IMPLICATION

Genetic correlations between reproductive traits of the first and later parities were not as high as expected. This indicates that reproductive traits of the sow should be analyzed considering first and later parities as different traits. The genetic correlations between productive and reproductive traits in the first and later parities should also be analyzed to compare the impact of correlated response and selection programs.

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