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Genetic Association between Age and Litter Traits at First Farrowing in a Commercial Pietrain-Large White Population in Thailand

Pranithi Pholsing[1], Skorn Koonawootrittriron[2,*], Mauricio A. Elzo[2] and Thanathip Suwanasopee[1]

ABSTRACT

Genetic associations between age at first farrowing (AFF), number born alive (NBA), stillborn and mummy (LOST) and total birth weight of live piglets (TBW) were estimated using data from 1777 Pietrain (PT) and 450 Large White (LW) sows gathered from 1999 to 2006 in a commercial swine population. All pigs were halothane gene negative, reared in an open-house system and given the same diet, management and health care. The variance and covariance for AFF, NBA, LOST and TBW were estimated using average information restricted maximum likelihood procedures and subsequently used to calculate heritabilities and genetic correlations. A four-trait animal model (AFF-NBA-LOST-TBW) was used that accounted for contemporary group (year-month) and breed as fixed effects and animal and residual as random effects. Large White pigs had shorter AFF (10.00 ± 2.34 d; $P < 0.01$), more NBA (1.20 ± 0.22 piglets; $P < 0.01$), less LOST (0.20 ± 0.11 piglets; $P < 0.01$) and lighter TBW (1.11 ± 0.30 kg; $P < 0.01$) than PT pigs. Heritability estimates were 0.06 ± 0.03 for AFF, 0.11 ± 0.04 for NBA, 0.08 ± 0.04 for LOST and 0.08 ± 0.03 for TBW. Genetic correlations between AFF and NBA (0.19 ± 0.26), LOST (-0.11 ± 0.33) and TBW (0.14 ± 0.32) were low. These low correlation estimates indicated that selection for AFF could be carried out in this commercial swine population without severe undesirable effects on litter traits.

Key words: age at first farrowing, litter traits, pig, tropical, genetic parameter

INTRODUCTION

Age at first farrowing (AFF) of a sow is associated with age to puberty and it is an economically important trait in swine production. This trait is related to longevity and lifetime productivity (Holder *et al.*, 1995; Serenius and Stalder, 2004). Reducing AFF resulted in a higher lifetime productivity (Holder *et al.*, 1995) and also related to a reduced risk of early culling (Tholen *et al.*, 1996; Yazdi *et al.*, 2000). At present, economic conditions have transformed the swine industry into an increasingly competitive business. Producers are striving to increase productivity and decrease costs. With this situation, the age at first farrowing (AFF) is an interesting trait. Applying this to determine the early replacement gilts could enable producers to generate more profit from the

[1] Department of Animal Science, Faculty of Agriculture, Kasetsart University Bgngkok 10900, Thailand.
[2] Department of Animal Sciences, University of Florida, Gainesville, Florida 32611-0910, USA.
* Corresponding author, email: agrskk@ku.ac.th

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raised parental stocks. Thus, the goal is to reduce costs by lowering the age at first farrowing without detrimentally affecting economically relevant litter traits.

Most databases on swine populations recorded AFF but it was for purposes other than genetic evaluation or selection (Rydhmer, 2000). Litter traits are the major component of sow productivity and their genetic improvement is an important breeding goal in swine. Furthermore, using parental pigs with a negative halothane gene to produce commercial pigs (e.g., replacement and hog) has taken a higher place in the swine industry. This has occurred because it can reduce the risk of the onset of malignant hyperthermia triggered under acute stressful conditions in pigs with a positive halothane gene, which may lead to death and to the development of pale, soft and exudative meat (McPhee *et al.*, 1994; Murray and Johnson, 1998; Fisher *et al.*, 2000). Thus, knowing the association between AFF and litter traits is necessary to optimize breeding schemes. The objective of this study was to evaluate the genetic association between the age at first farrowing (AFF) and the litter traits of: number born alive (NBA); stillborn and mummy (LOST); and total birth weight of live piglets (TBW); in a negative halothane gene, commercial Pietrain – Large White population raised in an open-house system in Thailand.

MATERIALS AND METHODS

Animals and data

The study was based on data from a commercial Pietrain (PT) – Large White (LW) swine population located in the central part of Thailand, which has been nearly closed for the past 10 years. With the exception of three outside boars imported from aboard (Belgium, Denmark and Germany), all boars and sows were replaced within the population each year. A system for testing for the halothane gene was implemented in this population in 1999. Since then, all replacement gilts and boars were tested for the halothane gene. Blood samples taken from tested animals were sent to the Molecular Biology Laboratory of Kasetsart University, Kampaeng Saen Campus, Nakhon Pathom province. If results from the laboratory test showed homozygous positive or heterozygous halothane gene genotypes, those pigs were culled from the purebred breeding units.

"Replacements (boars and gilts) were chosen primarily based on body size traits and leg conformation score (score system: 1 = extremely buckled, 2 = buckled, 3 = straight, 4 = sickled, and 5 = extremely sickled; Mathur, 2001) at first estrus. Pigs that had shoulder width larger than 28 cm, hip width larger than 28 cm, body length longer than 85 cm, and leg conformation score from 2 to 4 were selected as replacements." Approximately 40% of the pigs in the population were culled based on body size and leg conformation traits. In addition, piglets that had less than 12 nipples were culled after weaning. Further, gilts or sows that showed poor reproductive performance or had health problems were also culled. The main objective for this commercial swine population was to produce productive and healthy pigs for lean meat production.

Data for this study consisted of pedigree, age at first farrowing (AFF) and three litter traits: number born alive (NBA); stillborn and mummy (LOST); and total birth weight of live piglets (TBW). Table 1 shows the number of records, mean and standard deviation per breed for all traits. There were 1,777 AFF, NBA, LOST and TBW records for PT sows and 450 AFF, NBA, LOST and TBW records for LW sows. Pietrain sows were the daughters of 228 sires and 1,058 dams and LW sows were the progeny of 40 sires and 286 dams. Records were collected from 1999 to 2006.

Table 1 Mean and standard deviation for age at first farrowing (AFF), total born alive (TBA), stillborn and mummy (LOST) and total birth weight of live piglets (TBW).

Trait	Number of records	Mean ± SD
AFF (days)		
Pietrain	1,777	434.76 ± 34.21
Large White	450	428.34 ± 34.83
All breeds	2,227	433.46 ± 34.43
TBA (piglets)		
Pietrain	1,777	7.47 ± 2.62
Large White	450	8.58 ± 2.65
All breeds	2,227	7.69 ± 2.67
LOST (piglets)		
Pietrain	1,777	0.86 ± 1.46
Large White	450	0.66 ± 1.41
All breeds	2,227	0.82 ± 1.46
TBW (kg)		
Pietrain	1,777	11.10 ± 3.99
Large White	450	11.80 ± 3.71
All breeds	2,227	11.24 ± 3.94

Climate and management

Weather in central Thailand is influenced by tropical monsoons. Daily temperatures taken at the farm during the years of the study (1999 to 2006) ranged from 13.0°C to 35.5°C and humidity ranged from 17.2 to 100.0%. Seasons were summer (March to June; hot and dry), rainy (July to October; hot and humid) and winter (November to February; cool and dry).

All animals were raised in open buildings and received the same nutrition, management and health care during all stages of production. Gestating sows were kept in individual stalls and lactating sows were kept in individual farrowing pens. Floors (slats) in all barns were approximately 2.2 to 2.5 m above ground. Animals were raised on the floor, and the space under the floor was used for ventilation and drainage. In summer, when temperatures were too high (above 35°C), fans and water dripping were used to reduce heat stress.

Feed rations were pre-starter (22% protein; 3,600 Kcal DE), starter (19% protein; 3,400 Kcal DE), grower (18% protein; 3,300 Kcal DE), finisher (17% protein; 3,300 Kcal DE), gestation (14% protein; 3,000 Kcal DE) and lactation (17% protein; 3,300 Kcal DE). Feed ingredients for diets in all stages were broken rice, rice bran, soybean meal, fish meal, di-calcium phosphate, salt, vitamins and minerals. All diets were produced within the farm.

After farrowing, piglets were weighed individually and identified by ear notches and numbers tattooed in their ears. All piglets were allowed to nurse on their dam and were fed pre-starter and starter diets. The pre-weaning period ranged from 18 to 25 days. At weaning, all piglets were individually weighed and measurements of body size were taken (e.g. body length, width and height). After weaning, pigs were moved to replacement barns, penned in groups of 10 to 15 and fed 1.5 to 2.5 kg/d of a grower ration. Estrus detection was performed by trained personnel and recorded for gilts during their stay at the replacement barns. When gilts showed their first estrus, their age, weight and body size were recorded. If replacement gilts had good body condition, good health and weighed between 100 and 120 kg, they were mated to a selected boar of the same breed (Pietrain or Large White) using artificial insemination (up to two inseminations per gilt). Pregnancy was checked between 3 to 5 weeks after each mating. Subsequently, pregnant gilts were moved to individual stalls and fed 1.8 to 3.0 kg/d of a gestation ration. When gilts delivered their piglets, records were made of the date and age at farrowing (AFF = farrowing date – birth date), litter traits (NBA, LOST and TBW) and they were fed 2.0 to 2.5 kg/d of a lactation feed ration.

Data analysis

Statistical analysis utilized a four-trait animal model (AFF-NBA-LOST-TBW) that included contemporary group (year-month of birth of the sow) and breed (Pietrain, Large White) as fixed effects, with animal and residual as random effects. Additive relationships among animals were accounted for. The four-trait animal model is shown in Equation 1:

$$y = X\beta + Z_a a_a + e \qquad (1)$$

where
- y = vector of traits (AFF, NBA, LOST and TBW),
- β = vector of contemporary groups (year-month of birth of sow) and breed effects (Pietrain and Large White),
- a_a = vector of animal additive genetic effects,
- e = vector of residuals,
- X = matrix of 1's and 0's relating sow records to elements of vector β,
- Z_a = matrix of 1's and 0's relating sow records to elements of vector a_a,

The assumptions of the model were:

$$\begin{bmatrix} \mathbf{y} \\ \mathbf{a_a} \\ \mathbf{e} \end{bmatrix} \sim \left(\begin{bmatrix} \mathbf{X} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix}, \begin{bmatrix} \mathbf{Z_a G_a Z_a'} + \mathbf{R} & \mathbf{Z_a G_a} & \mathbf{R} \\ \mathbf{G_a Z_a'} & \mathbf{G_a} & \mathbf{0} \\ \mathbf{R} & \mathbf{0} & \mathbf{R} \end{bmatrix} \right)$$

Matrix $G = G_o \otimes A$,

where G_o is a 4 × 4 matrix of additive genetic variances and covariances among traits (AFF, NBA, LOST and TBW),
A is the numerator relationship matrix among animals (Henderson, 1976),
$\otimes$ represents direct product (Searle, 1982).

Matrix $R = I{*}R_o$ is the residual covariance matrix,

where I is an identity matrix, and
R_o is a 4 × 4 matrix of residual variances and covariances among AFF, NBA, LOST and TBW.

Estimates of the variance and covariance components between AFF, NBA, LOST and TBW were estimated using restricted maximum likelihood procedures (Harville, 1977). These variance and covariance estimates were then used to estimate heritability for and genetic correlations among AFF, NBA, LOST and TBW. Computations were carried out with the ASREML program (Gilmour *et al*., 2000).

RESULTS AND DISCUSSION

Data

The least squares means for the contemporary groups ranged from 319.30 ± 17.85 to 480.80 ± 11.08 days for AFF, 6.16 ± 1.31 to 12.84 ± 1.82 piglets for NBA, 0.03 ± 0.36 to 2.25 ± 0.84 piglets for LOST and 7.31 ± 1.94 to 20.32 ± 2.70 kg for TBW. Sows in this P-LW population had different and wider ranges for AFF, NBA, LOST and TBW than values reported in the literature (Tummaruk *et al*., 2001; Serenius *et al*., 2004; Johnson *et al*., 2005). These differences and the larger variability among sows may be the result of the tropical environmental conditions in central Thailand, variability in management across years and genetic differences between PT and LW swine populations. Sows were kept in an open-house system at all times, thus they were exposed to a wide range of ambient temperatures (13.0 to 35.5 °C) and humidity (17.2 to 100.0%), wind speed and photoperiods, which were likely to have been associated with variations in comfort and stress conditions. Furthermore, fans and water dripping were only used to reduce heat stress when temperatures rose above 35°C. Other factors such as excess humidity, wind speed and photoperiod were not managed. The variability in humidity and other environmental factors across months and years was most likely to have had some influence on the age and litter traits at first farrowing.

Additional environmental factors that may have affected variability among sows across years include personnel and the quality and type of feed ingredients. Commercial farms in Thailand often hire foreign personnel (Burmese or Laotians) to reduce the costs of production. Foreign employees usually have little or no experience in swine husbandry and they tend to change jobs frequently. To help reduce the variability among sow traits under an open-house system, management, environmental conditions, feed ingredients and the quality of personnel need to be improved and made more uniform over time.

Breed effect

Estimates of breed effects for AFF, NBA, LOST and TBW are presented in Table 2. Pietrain had longer AFF (10.00 ± 2.34 days; P < 0.01), lower NBA (1.20 ± 0.22 piglets; P < 0.01), higher LOST (0.20 ± 0.11 piglets; P < 0.01) and lighter TBW (1.11 ± 0.30 kg; P < 0.01) than LW (Table 2). Differences between PT and LW for AFF, NBA, LOST and TBW may have been due to differences in energy body reserves.

Pietrain is a leaner breed that is known to have lower body energy reserves than LW (Moody *et al*., 1978). Lower energy reserves have been found to have a negative impact on reproduction (Whittemore, 1996; Grandinson *et al*., 2005). Lower energy reserves in PT sows may have decreased their performance for AFF and litter traits relative to LW sows. These results agreed with Stalder *et al*. (2005) who found that back fat had significantly influenced AFF, life time NBA and the number of parities. Thus, the results from the current study lend support to the idea in commercial swine crossbreeding programs of using LW as a maternal breed because of its superiority for litter traits (high NBA, low LOST and large TBW), and PT as a paternal breed for its desirable meat and carcass traits (high lean production and muscularity). In addition, LW had shorter AFF than PT. With this advantage LW could have a longer length of productive life than PT.

Genetic variance, covariance, heritability and correlations

Table 3 shows estimates of heritability for and genetic and phenotypic correlations among AFF, NBA, LOST and TBW. Estimates of genetic variance were 61.32 ± 29.62 day^2 for AFF, 0.75 ± 0.25 piglets^2 for NBA, 0.17 ± 0.07 piglets^2 for LOST and 1.14 ± 0.49 kg^2 for TBW. Estimates of heritability were 0.06 ± 0.03 for AFF, 0.11 ± 0.04 for NBA, 0.08 ± 0.04 for LOST and 0.08 ± 0.04 for TBW. Heritability estimates for AFF here were lower than values reported for Duroc (0.19;

Table 2 Estimates of breed effects for age at first farrowing (AFF), number born alive (NBA), stillborn and mummy (LOST) and total birth weight of live piglets (TBW).

Trait	Breed effect(Pietrain-Large White)	P-value
Age at first farrowing (days)	10.00 ± 2.34	0.0001
Number born alive (piglets)	-1.20 ± 0.22	0.0001
Stillborn and mummy (piglets)	0.20 ± 0.11	0.0001
Total birth weight of live piglets (kg)	-1.11 ± 0.30	0.0001

Table 3 Heritability (diagonal), genetic correlations (above diagonal), and phenotypic correlations (below diagonal) between age at first farrowing (AFF), number born alive (NBA), stillborn and mummy (LOST) and total birth weight of live piglets (TBW).

Traits	AFF (days)	NBA (piglets)	LOST (piglets)	TBW (kg)
AFF (days)	**0.06 ± 0.03**	0.19 ± 0.26	-0.11 ± 0.33	0.14 ± 0.32
NBA (piglets)	-0.03 ± 0.02	**0.11 ± 0.04**	-0.65 ± 0.18	0.92 ± 0.04
LOST (piglets)	-0.00 ± 0.02	-0.49 ± 0.02	**0.08 ± 0.04**	-0.60 ± 0.21
TBW (kg)	0.00 ± 0.02	0.91 ± 0.01	-0.49 ± 0.02	**0.08 ± 0.03**

Johnson *et al*., 2005), Landrace (0.26 to 0.40; Johnson *et al*., 2005; Serenius and Stalder, 2004; Serenius *et al*., 2004), and LW (0.35 to 0.39; Serenius and Stalder, 2004; Serenius *et al*., 2004) populations.

The low heritability estimates found in this study may have been influenced by: i) the high variability in temperature and humidity within and across years in central Thailand (heavily affected by monsoon weather); ii) limited genetic variability in the breeding population due to within herd replacement of all but three boars and all sows for the past 20 years; and iii) a large variation in the quality of management and data collection due to frequent changes of personnel. Thus, although positive changes due to selection for AFF, NBA, LOST and TBW are feasible, larger changes would be expected from improvement in management aspects than from selection for these traits.

Estimates of genetic covariance were 1.29 ± 1.93 days*piglets between AFF and NBA, -0.38 ± 1.06 days*piglets between AFF and LOST, 1.19 ± 2.70 days*kg between AFF and TBW, -0.23 ± 0.11 piglets^2 between NBA and LOST, 0.86 ± 0.34 piglets*kg between NBA and TBW and -0.26 ± 0.15 piglets*kg for LOST and TBW. Phenotypic covariance estimates were -2.36 ± 1.74 days*piglets between AFF and NBA, -0.05 ± 0.97 days*piglets between AFF and LOST, 0.02 ± 2.57 days*kg between AFF and TBW, -1.82 ± 0.09 piglets^2 between NBA and LOST, 9.00 ± 0.29 piglets*kg between NBA and TBW, and -2.69 ± 0.13 piglets*kg between LOST and TBW.

Estimates of genetic correlations between AFF and litter traits (NBA, LOST and TBW) were low and had large standard errors, while estimates of the phenotypic correlations between these traits were all near zero (Table 3). These estimates of genetic and phenotypic correlations suggest that improving AFF in this commercial swine population would have had no undesirable effects on litter traits (NBA, LOST and TBW).

The age of gilts has been suggested as the primary factor determining the onset of puberty (Newton and Mahan, 1993). Age at puberty, in turn, will affect age at first conception and age at first farrowing. Thus, mating gilts at younger ages should reduce age at first conception and AFF. However, this may not occur in all gilts. Archibong *et al*. (1987) found that gilts mated at first estrus had higher embryonic mortality 30 days after mating than gilts mated at the third estrus. Further, Schukken *et al*. (1994) found that gilts with inherent low fertility became pregnant at older ages and subsequently had a higher probability of being culled for reproductive failure. Thus, differences in genetic background and the physiological status of gilts should be considered before moving gilts into the breeding herd. Consequently, commercial swine producers would need to consider genetic, physiological, nutritional and external environmental factors to identify successfully sows that would reach AFF at younger ages and have high levels of production.

CONCLUSIONS

Pietrain progeny had longer AFF, lower NBA, higher LOST and lighter TBW than Large White. Heritability estimates for AFF and litter traits (NBA, LOST and TBW) were low, indicating that nutrition, management and climate heavily influenced the phenotype of these traits. Genetic correlations between AFF and litter traits were low and phenotypic correlations were zero, suggesting that selection for younger AFF would not be detrimental to litter traits in this swine population.

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