Evaluation of litters per sow per year as a means to reduce non-productive sow days in commercial swine breeding herds and its association with other economically important traits

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Evaluation of litters per sow per year as a means to reduce non-productive sow days in commercial swine breeding herds and its association with other economically important traits

by

Caitlyn Elizabeth GeneAnn Hoots Abell

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Animal Breeding and Genetics

Program of Study Committee:
Kenneth Stalder, Major Professor
John Mabry
Jack Dekkers
Philip Dixon

Iowa State University
Ames, Iowa

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ABSTRACT

The purpose of this project was to determine the value of implementing litters per sow per year (LSY) into a selection program. Two studies were conducted to achieve this objective. The goal of one study was to determining the genetic and phenotypic relationships between LSY and other economically important reproductive and post-weaning traits from a commercial swine breeding company. Determining the genetic and phenotypic correlations among traits can help breeders evaluate the expected impacts their selection decisions have on other economically important production traits. These other economically important traits may or may not be included in the selection criteria. This is particularly important when considering reproductive and post-weaning traits because of the undesirable genetic relationships that typically exist between reproductive and post-weaning traits. The traits collected included number born alive (NBA), wean to estrus (W2E), adjusted back fat (BF), percent lean (PCL), and days to 100 kg (D100). Litters per sow per year (LSY) was calculated based on recorded information. Genetic parameter estimates were calculated using ASREML. The heritability estimates for NBA, LSY, W2E, BF, D100, and PCL were 0.15, 0.03, 0.03, 0.52, 0.33, and 0.36, respectively. The genetic correlation between LSY and W2E was large and favorable. The genetic correlations between LSY and the three post-weaning traits (BF, D100, and PCL) have large standard errors and are unclear in direction. Some economically important traits can be favorably changed indirectly with selection on LSY; however, a selection index will be needed to ensure that post-weaning growth traits are not adversely affected by selection for LSY in a maternal line breeding program. The goal of the second study was to determine the relationship between individual sire breeding values (BV) for LSY and progeny means for farrowing rate, removal parity, and lifetime born alive.
Landrace, Large White, and F₁ (Y×L or L×Y) crossbred females were included in the analyses. Estimated breeding values (EBV) for LSY were calculated using ASREML. The heritability estimate for LSY was 0.11. Sire progeny (daughter) farrowing rate means were calculated as total number of services of the sire’s daughters divided by the total litters farrowed from the sire’s daughters. Similar values were calculated for daughter average removal parity, and daughter average lifetime born alive. The Spearman rank correlation between the LSY EBV and the progeny farrowing rate of the sires was calculated using SAS software. When all sires with 10 or more daughters were included in the analysis, the Spearman rank correlations between the sire’s LSY EBV and daughter means for farrowing rate, removal parity, and lifetime born alive were 0.49, 0.23, and 0.25 (P<0.01). The LSY EBV was favorably correlated with the daughter means for all three traits. This provides evidence that selecting sires with high LSY EBV to improve the LSY could also improve the herd farrowing rate, removal parity, and lifetime born alive. Sires ranked in the top 25% for LSY EBV had a 15.3% higher average farrowing rate compared to sires in the bottom 25%. Daughters from the top sire had a one parity greater average removal parity than daughters from the other sire group. This extra litter corresponded to an average of 8.9 more pigs produced in a sow’s lifetime. Based on the results of this project, LSY is heritable. There is a genetic component of LSY and there is sufficient biological variation of the trait for traditional selection methods to be efficient and effective. There are little to no antagonistic relationships between LSY and the other economically important traits considered in this study. A selection index must be employed to ensure that there is no adverse effect on other economically important traits when selecting for LSY. There is evidence to suggest that a desirable relationship exists between LSY and farrowing rate, removal parity, and lifetime
born alive. Improving farrowing rate through improving LSY can reduce the number of costly non-productive sow days in the herd. Improving removal parity and lifetime born alive through increasing LSY could improve sow longevity.
CHAPTER 1: GENERAL INTRODUCTION

The present study examines the use of litters/sow/year (LSY) as a means to improve non-productive sow days and to evaluate its relationship with other economically important traits. The first objective was to estimate the genetic parameters for LSY. If LSY is a not a sufficiently heritable trait with sufficient genetic variation, little, if any, progress would be expected through traditional selection methods.

The second objective of this study was to determine the genetic and phenotypic relationships between LSY and other economically important reproductive and post-weaning production traits. When selecting for LSY it is important to understand the effect selection will have on other economically important traits. If there is no genetic correlation between LSY and another trait, then selection for LSY is not expected to improve the trait. On the other hand, selection for LSY would not adversely affect the trait, which would be beneficially in the case of post-weaning growth traits. It is important to know if the trait has a large unfavorable correlation with economically important growth, reproduction, and carcass cutability traits.

Litters per sow per year is calculated by using the total gestation days for a female and the total mated female days. The components of LSY include weaning to estrus interval, farrowing interval, farrowing rate, and gestation length. These components have been shown to be heritable (Adamec and Johnson, 1997; and Hanenberg et al., 2001). The fact that the components of LSY are heritable suggests that LSY is also heritable. Gestation length is a heritable trait that does not have sufficient variation in order for selection to change it. There are also biological constraints to changing the gestation length. If the gestation length is too
short, the piglets will not be fully developed. The weaning to estrus interval is also biologically limited. Time is required after weaning before the sow will come into estrus.

The largest opportunity for improvement in LSY would be in decreasing the time from weaning to the next successful mating. Sows that are not successfully mated during their first estrus after weaning accumulate many non-productive days, because the sows must complete another estrous cycle before they can be mated again. While there is a large management component to the successful re-breeding of a sow, there may be a genetic component. Incorporating LSY in a selection program may be a method to take advantage of the genetic component of non-productive days.

The LSY in individual swine operations can be greatly impacted by the number of non-productive days in the sow herd (Koketsu, 2005). If a sow is not gestating or lactating, she is not producing pigs which are the saleable products that generate income for commercial pork operations. Every non-productive day incurred for a sow costs the producer anywhere from $1.60 to $2.60 (Rix and Ketchem, 2009). This would mean that one fewer non-productive day per sow per year would reduce costs of a 1,000 sow operation by approximately $1,600 to $2,900 annually. Improving the LSY for breeding herd females will increase gross income for the swine operation by reducing non-productive sow days in the herd.

If selection of LSY can improve other economically important traits such as increasing sow lifetime production and reducing the number of non-productive sow days, then selection for LSY can have a large impact on the profitability of swine operations. Increasing the productive lifetime of sows in the breeding herd allows for the variable costs of gilt development to be spread over more piglets produced in the sow’s lifetime.
lifetime production greatly impacts the lifetime productivity and hence, the profitability of commercial swine production. If a sow does not remain in the herd for multiple parities, she has not had sufficient time to pay for herself or to be sufficiently productive to generate adequate profit to recover the initial gilt purchase price plus the associated gilt development costs (Stalder et al., 2000).

Litters per sow per year could be used to determine the expected productive lifetime of the sow. Sows are culled when a producer believes that the sow is likely no longer sufficiently productive and therefore, not profitable and should not be retained in the herd. Sows are typically culled for reproductive failure (failure to cycle, failure to conceive, found open at some time period after mating, etc.) (Mote et al., 2009). Since LSY is a measure of the reproductive performance of the sow, it could improve the lifetime production of the sow by preventing or reducing culling due to reproductive performance.

**Thesis Organization**

A comprehensive literature review follows this introduction. After the literature review, modified versions of two papers to be submitted to *Livestock Science* are included to achieve the objectives of this thesis. The first paper presents the variance component estimates of LSY and other economically important reproductive and post-weaning traits. Genetic and phenotypic correlations among the traits are presented as well. The second paper presents the relationship between LSY and farrowing rate, removal parity, and lifetime pigs born alive.
CHAPTER 2: LITERATURE REVIEW

Litters/Sow/Year

Litters per sow per year (LSY) is defined as the number of litters farrowed divided by the number of years the sow is in the herd. This can be calculated by using the total number of gestation days and total number of mated female days:

\[
\frac{(\text{number of days gestating})/115}{(\text{number of days in the breeding herd})/365}\]  

(Stalder, 2002).

Using 115 days for gestating, 21 days lactating, and 5 days weaning to estrus, the maximum number of LSY is 2.6 litters. The average LSY in US herds is approximately 2.27, suggesting that there is considerable efficiency that can be gained by improving the LSY in commercial sow herds in the U.S. (PigCHAMP, 2010). The components of LSY that can be improved through the improvement of LSY include farrowing rate, wean to service interval, and non-productive days. The components of LSY are heritable, suggesting that LSY is heritable as well. While gestation length is heritable, there is little variation in the trait, and there are biological limitations to reducing the gestation length.

Koketsu et al. (1997) extracted 12,110 farrowing records from 16 commercial farms that employed an early weaning (average <19 d) management system, PigCHAMP™ (Farms.com, Ames, IA). Farrowing rate tended to increase as lactation length increased, as average daily feed intake increase, and as parity of the sow increased. Farrowing rate was lowest during the summer months. A weaning to service interval less than 7 days or greater than 12 days resulted in a 5% increase in farrowing rate compared to a weaning to service interval between 7 and 12 days.
King et al. (1998) used data from 673 U. S. farms who participated in the PigCHAMP™ (Farms.com, Ames, IA) data-share program to analyze the effect of various management factors on productivity of breeding herd. The researchers used PROC REG in SAS to determine the effect of management factors on multiple reproductive performance measurements. Percent of multiple matings, percentage of breeding females that are gilts, and the region where the farm is located were significant effects on breeding herd female non-productive days. An increased percentage of multiple matings decreased the number of non-productive days in the herd. Increasing the percentage of replacement gilts in a breeding herd increases the number of non-productive days in the herd. Litters/mated female/year was significantly affected by lactation length and percent of multiple matings. An increase in the percent of multiple matings increased the number of litter/mated female/year. This is a result of the increased farrowing rate associated with multiple matings. An increase in the lactation length of the herd reduced the number of litter/mated female/year. Lactation length, percent of multiple matings, and female culling rate were significant effects on the number of pigs weaned/mated female/year. Increasing the percentage of multiple matings in the herd increased the number of pigs weaned/mated female/year. Increasing the lactation length and the female culling rate decreased the number of pigs weaned/mated female/year. Multiple matings had a favorable relationship with reproductive performance measurements.

Omtvedt et al. (1965) obtained 601 litter records over a 5 year period from Oklahoma Agricultural Experiment Station. The records were from 301 sows and 390 gilts. The objective of the study was to determine the effect of gestation length, age at breeding, weight at breeding, and gestation gain on the productivity of the sow at farrowing. Trait values were adjusted for station, season, genetic line, and age of sow. Sows had one more pig born per
litter and a 3 kg larger litter birth weight compared to gilts. Gestation length had significant
correlations of -0.16, 0.12, and -0.12 with litter size at birth, pig weight at birth, and litter
birth weight, respectively. This suggests that increased gestation length increases individual
pig weight and that litters with more piglets tend to be born at an earlier gestation age than
litters with fewer piglets. Age at breeding is correlated with breeding weight, litter size at
birth, pig weight at birth, and litter birth weight, with values of 0.55, 0.12, 0.16, and 0.19,
respectively. Increased age at breeding was associated with increased the litter size and pig
birth weight of the sow, but negatively impacted longevity. The correlation between gestation
gains and litter size at birth and pig weight at birth was -0.14 and 0.16, respectively. The
more weight a sow puts on during gestation, the heavier pigs are at birth; however, the litter
size is smaller. Litter size had correlations of -0.55 and 0.83 with pig weight at birth and litter
birth weight. This would suggest that the capacity of the sow is limited and larger litters
results in lower individual piglet birth weights.

Rydhmer et al. (2008) used 12,708 Yorkshire litter records from first-parity sows and
7,062 Yorkshire litter records from second-parity sows. The data was obtained from Swedish
nucleus herds. Another 1,037 litter records from an experimental herd were also included in
the analysis. For the nucleus herds, data was analyzed using a model with farrowing month
as a fixed effect and herd-year, mating type, sire, and dam as random effects. For the
experimental herd, data were analyzed using farrowing batch as a fixed effect and sire and
dam as random effects. The analyses were conducted using AI-REML in the DMU software
package.

The first and second parity litters were analyzed separately. For the first-parity sows
in the nucleus herds, heritabilities for gestation length, total born, number born alive, and
number of stillborn were estimated to be 0.33, 0.10, 0.10, and 0.05, respectively. For second-parity sows in the nucleus herds, heritabilities for gestation length, total born, number born alive, and number of stillborn were estimated to be 0.31, 0.03, 0.03, and 0.04, respectively. Estimates of genetic correlations between gestation length and total born, number born alive, and number of stillborn were 0.04, 0.03, and 0.04 for first-parity sows in the nucleus herds, and 0.11, 0.20, and -0.20 for second-parity sows in the nucleus herds. The biggest difference between first and second parity sows was the correlation between gestation length and number of stillborn. First-parity sows had a positive genetic correlation between gestation length and number of stillborns, while this correlation was negative for second-parity sows.

Adamec and Johnson (1997) conducted a study using nucleus herds in the Czech breeding program that did not use hormones to enhance estrus. They used data from 5 companies for a total of 12,081 records on 2,896 sows. The sows were Large White (1,565) and Landrace (1,331). The authors used the GLM procedure in SAS to estimate the heritabilities and EBV’s for each trait in the analysis. The model included unit, breed, parity, year and month of farrowing, and all significant two-way interactions. Weaning age was fitted as a covariate for total number weaned. Litter weaning weight, weaning to service interval, weaning to conception interval, and weaning to farrowing interval. Final weight was fitted as a covariate for average daily gain and backfat.

The heritabilities for weaning to service, weaning to conception, and weaning to farrowing intervals were estimated to be 0.14, 0.06, and 0.05, respectively. Heritabilities for total number born, number born alive, number weaned, and litter weaning weight were estimated to be between 0.08 and 0.11. The heritability of backfat was reported as 0.37, and the heritability of average daily gain was reported as 0.10. The genetic correlations of
weaning to service interval with total number born, number born alive, number weaned, litter weaning weight, backfat, and average daily gain were 0.13, 0.07, 0.13, 0.16, -0.10, and -0.04, respectively. The genetic correlations of weaning to conception interval and weaning to farrowing interval agree with the above correlations for backfat, number born alive, and litter weaning weight; however, the correlations with total number born, average daily gain, and number weaned are not similar with the above correlations. The genetic correlation between total number born and weaning to conception interval is -0.08, and the correlation with weaning to farrowing interval is 0.21. The genetic correlation between average daily gain and weaning to conception interval is 0.18, and the correlation with weaning to farrowing interval is 0.20. The correlation between number weaned and weaning to conception interval was estimated to be -0.01, and the correlation with weaning to farrowing interval was estimated to be -0.16.

This suggests that backfat is unfavorably correlated with wean to service interval, wean to conception interval, and wean to first service interval. Average daily gain is unfavorably correlated with weaning to farrowing and weaning to conception intervals and favorably correlated with weaning to service interval. As average daily gain increased the weaning to farrowing and weaning to conception interval increased while the weaning to service interval decreased. Total number born is favorably correlated with weaning to service and weaning to farrowing intervals, but is unfavorably correlated with weaning to conception interval. The standard errors were not reported and it is unclear if the correlation were significantly different from zero.

Hanenberg et al. (2001) used data from 158,194 Dutch Landrace sows in parities 1-6 to estimate genetic parameters for several sow reproductive traits. The analyses were
computed using DFREML. Fixed effects included in the model were parity, contemporary group, service boar, and number of inseminations. Lactation period, number weaned, and interval from weaning to insemination were included in the model as covariates.

The authors reported heritability estimates of 0.25, 0.14, and 0.03 for gestation length, weaning to first insemination interval, and farrowing after first insemination. The heritabilities for older sows (parities 2-6) were found to be 0.29, 0.07, and 0.01, respectively. Gestation length tended to have a positive genetic correlation across parities with weaning to insemination interval, mothering ability, and age at first insemination. Genetic correlations were moderate for mothering ability and low for weaning to insemination interval and age at first insemination. Gestation length tended to have a low to moderate negative genetic correlation across parities with total number born and farrowing after first insemination. While there is little variation in gestation length, the moderate genetic correlations suggest that a 1 day change in gestation length can have significant effects on other biological traits of the sow and her piglets.

In general, interval from weaning to insemination had a low to moderate positive genetic correlation with mothering ability and a moderate positive correlation with age at first insemination. The genetic correlation between interval from weaning to insemination and farrowing after first insemination was moderate and negative. There was a moderate positive genetic correlation estimate between age at first farrowing and farrowing after first insemination. Again, these correlations were not presented with standard errors and are not shown as significantly different from zero.

Increasing the LSY for a commercial breeding herd should increase the farrowing rate and reduce the non-productive days of the herd due to the favorable genetic correlation
between the traits. A higher LSY should result in a shorter weaning to conception interval which suggests fewer services and days before conception. Koketsu (2005) conducted a study to find a relationship between pigs weaned per mated female per year, non-productive days, and farrowing rate. Data was collected from 95 farms using the PigCHAMP™ (Farms.com, Ames, IA) system in Japan. Koketsu (2005) found a correlation between nonproductive mated female days and farrowing rate to the -0.69 in herds ranked in the upper 25th percentile for pigs weaned per sow mated female per year. The correlation was -0.81 in average herds. Koketsu reported that for every 10 fewer nonproductive days, LSY will increase by 0.07, and with every 0.1 increase in LSY pigs weaned per sow per year will increase by 0.9. This would result in a 0.74 increase in pigs weaned per mated female per year for high performing sows and 0.63 pigs in ordinary farms.

Increasing LSY can greatly impact the profit of a commercial pork operation. Increasing the average LSY of a herd has the potential to reduce costs by reducing the number of non-productive days in the herd and to increase income by producing more weaned pigs per year. The cost of a non-productive day is between $1.60 and $2.60 per sow (Rix and Ketchem, 2009). The average number of non-productive days in a herd is approximately 35 days per year. This is a cost of between $56 and $91 per sow per year. Assuming a cost a $2.00 per non-productive day per sow, a breeding herd with 2,400 sows can save $24,000 a year by reducing their average non-productive days by 5.

Suwanasopee et al. (2005) analyzed the relationship between number born alive and weaning to estrus interval using 13,289 records on 3,542 sows from Thailand. The software used for the analysis was ASREML. Heritability estimates were 0.07 and 0.03 for number born alive and weaning to estrus interval, respectively. The genetic and phenotypic
Correlations were estimated to be -0.01 and -0.00, respectively. These results suggest that selecting for reduced weaning to estrus should not negatively impact number born alive.

Stein et al. (1990) utilized records from 80 North American herds that used specific herd management software. Only herds that had complete records and a constant female inventory. The 80 herds had an average female inventory of 261.8. Herds were divided into high and low productivity groups. Herds were considered to be highly productive if they were in the top quartile for pigs weaned per female per year. Low-productivity herds were in the bottom quartile. The mean pigs weaned per year for the high-productivity herds was 20.8 pigs. The mean for the low-productivity herds was 15.6 pigs.

Total pigs born per litter and pigs born alive per litter were almost 1 pig more for the high-productivity herds compared to the low-productivity herds. The proportion of gilts in the high-productivity herds was 16.8% compared to 23.3% for the low-productivity herds. This suggests that sows are more productive than gilts. The pre-weaning mortality in the high-productivity herds was 6% lower than the pre-weaning mortality in the low-productivity herds. The farrowing rate was 7% higher and there were 30 fewer non-productive days for the high-productivity herds. The litters per sow per year was 2.22 for the high-productivity herds while the litters per sow per year for the low-productivity herds was 1.98. Litters per sow per year was found to have a favorable correlation of -0.87 with annual non-productive days. The correlation between LSY and pigs weaned per females per year was estimated to be 0.68. Litters per sow per year and farrowing rate were found to be favorably correlated (0.51). These results suggest that improving LSY in the herd can improve the productivity of the herd in terms of pig weaned per year by reducing the number of NPD in the herd and increasing the herd farrowing rate.
**Sow Longevity**

Sow longevity can be defined as total piglets born in the sow’s lifetime (lifetime production), total days in the breeding herd (length of productive life) or a combination of the two (pigs produced per day of herd life). Sow longevity has a low to moderate estimated heritability. Serenius and Stalder (2004) used data on 26,744 Landrace and 24,007 Large White sows from the Finnish Animal Breeding Association to estimate genetic parameters of lifetime traits. The DMU software package was used to do the analysis of the lifetime traits. Contemporary group, leg score, and number weaned in the first litter were fitted as fixed effects. The sire was fitted as a random effect. Age at first farrowing was fitted as a covariate. The authors estimated the heritability of length of productive life (LPL) using survival analysis to be 0.16 and 0.17 for Finnish Landrace and Large White sows, respectively. Using a linear model, the authors estimated heritability to be 0.05 for Landrace and 0.10 for Large White. Lifetime number of pigs produce (LTP) was also estimated using a linear model in the study to be 0.09 and 0.12 for Landrace and Large White, respectively.

In the Finnish Landrace population, the genetic correlation between LPL and LTP was 0.96 ± 0.02. Both traits had a moderate and positive genetic correlation with number weaned and leg score and a moderate and negative genetic correlation with first farrowing interval. In the Finnish Large White population, the genetic correlation between LPL and LTP was 0.97 ± 0.01. Genetic correlations with number weaned and first farrowing interval were similar to those in the Landrace population. Both traits were negatively correlated with age at first farrowing and positively correlated with backfat. The genetic correlations with leg score were positive, but lower than those for the Landrace population.
Serenius et al. (2008) used records on 11,222 Finnish Landrace sows. The authors estimated the heritability of LPL to be 0.22 in the Finnish landrace population using a Gibbs sampling method. The genetic correlations between LPL and number wean, age at first farrowing, and litter weaning weight were estimated to be $0.36 \pm 0.15$, $-0.20 \pm 0.14$, and $-0.05 \pm 0.18$, respectively.

Sows in higher parities tend to have improved production performance over parity 1 females. Moeller et al. (2004) compared the female productivity of six maternal lines. Data was obtained from two breed-to-wean production units. The National Pork Producers Council collected the data as part of the Maternal Line National Genetic Evaluation Program. A total of 8,424 litter records were used to analyze differences among lines for sow longevity and performance through parity 4. Line, parity, production unit, and interactions were fitted as fixed effects in the models used to analyze the traits. Random effects included in the analysis were contemporary group, and permanent environment. For the appropriate traits, lactation length was fitted as a covariate. Of the 2,592 sows that farrowed at least one litter, 1,656 completed the fourth parity. Sows in parity 2, 3, or 4 had a higher live litter birth weight compared to parity 1 females. Higher parity sows also tended to have larger litter weaning weights and a higher number weaned per litter across most of the genetic lines compared in the study. Parity 2+ sows lost less backfat and weight during lactation compared to parity 1 females. They also had greater total feed intake during lactation.

Serenius et al. (2006) used 3,251 gilt records from 6 different genetic lines to examine the effect of different traits on the risk of being culled. Of the gilts, only 78.4% successfully farrowed at least one litter. The Maternal Line Genetic Evaluation Program conducted by the National Pork Producers Council was the course of the data used in this analysis. The study
analyzed the effect of gilt backfat, average daily gain, live weight, feed intake, backfat age at first farrowing, and total number born on the risk of culling in each of the 6 lines. Effects were considered significant if the amount of variation explained by the full model including all effects plus the effect of interest was significantly larger than the amount of variation explained by the reduced model not including the effect of interest. The study showed that, for 5 of the 6 lines, increasing the feed intake of the sow reduced the sow’s risk of being culled. For 4 of the 6 lines, decreasing the backfat loss of the sow decreased the sow’s risk of being culled. Gilt backfat, average daily gain, live weight, age at first farrowing, and total number born did not have significant effects on the risk of culling for the majority of the lines.

Sows with a greater length of productive life have been shown to have a greater number of piglets born alive per litter, lower weaning to first mating interval and farrowing rate. Sasaki and Koketsu (2008) evaluated 66,370 records from 13,786 sows from 92 herds in Japan who use PigCHAMP™ software (Farms.com, Ames, IA). Sows were divided into three categories based on their lifetime production. High efficiency and high longevity sows were those that produced 21.5 pigs per year and were culled after 6 or more parities (3000 sows). Sows with ordinary efficiency were not in the upper 25th percentile for efficiency, but were culled after the 6th parity (3379 sows). The rest of the sows were in the low longevity group (7407 sows). Of the high efficiency and high longevity sows, 81.9% of the sows were culled due to old age. Of the ordinary efficiency and high longevity sows, 67.2% were culled due to old age. Of the low longevity sows, 39.3% were culled due to reproductive failure; the second largest category was miscellaneous at 35.8%. Culling due to poor reproductive performance could be a result of failure to come into estrus, failure to conceive, and failure to
farrow. This data would imply that sows who are able to remain in the herd for 6 or more parities are not culled due to performance like younger sows.

Sasaki and Koketsu reported that sows high lifetime efficiency and high longevity to have 2 or more piglets born alive for parities 1-5 compared to sows with low longevity. This would be a total of at least 10 more piglets. At $30 per pig, this is an increase in revenue of at least $300 per sow. High longevity sows had a >20% higher farrowing percentage and 1-2 fewer days from weaning to first mating than low longevity sows in parities 1-5. The authors also reported a phenotypic correlation of 0.52 between litters per mated female per year and the proportion of sows classified as high longevity and high efficiency sows. When the proportion of sow in the high longevity and high efficiency group increased, the LSY increased. The proportion of sows classified as low longevity sows showed a phenotypic correlation of -0.44 with litters per mated female per year. When more sows were in the low longevity group, the LSY was lower. These correlations imply that sows who stay in the herd longer tend to have a higher LSY than sows who remain in the herd for only a few parities. This suggests the potential for a positive correlation between longevity and LSY.

Mote et al. (2009) used 2,000 breeding age females from one large commercial farm to evaluate removal reasons among sows in a commercial herd. The primary reason for removal of young sows (parity < 5) is poor reproductive performance. Reproduction was listed as the reason for removal of 35.1% of sows removed before parity 5. For older sows (parity > 5), culling for poor reproductive performance (12.2%) is second only to culling due to old age (48.2 %). This also suggests a correlation between LSY and longevity since LSY is one measurement of reproductive performance. One component of LSY is rebreeding interval. If a sow fails to conceive, her LSY increases. Sows that fail to conceive tend to be
culled due to poor reproductive performance. Sows culled at parity 5 or after tended to have higher total number born and number born alive in the first four parities than sows that were culled before parity 5.

Friendship et al. (1986) analyzed data on 30 farms in Ontario, Canada for two years in order to analyze the reasons for sow removal and the removal rate at the farms. Reproductive failure was the main cause of sow removal from the herds. Approximately 43% of the sows removed were removed due to reproductive failure. Approximately 30% of the sows were removed due to health and physical problems; this percentage was reduced to 24% during the winter. The average removal rate among the herds was 44%. The phenotypic correlation between removal rate and average number of pigs born alive per litter was -0.50, and the phenotypic correlation between removal rate and average number of pigs weaned per litter was -0.42. The phenotypic correlation between removal rate and percent of litters with 8 or fewer pigs born alive was 0.53. These correlations are unfavorable and suggest that greater removal rates result in lower production efficiency in the operation.

Kroes and Van Male (1978) used 15,000 service records from 85 commercial farms to analyze the relationship between sow productive lifetime and weaned pigs per sow per year. The Dutch National Agricultural Advisory Service and the Agricultural Economic Research institute. The average replacement rate was 43%. Sows in parities 2 or higher weaned 8.6 or more pigs per litter compared to parity 1 females. Farms with a relatively low culling rate (31.3%) produced 17.9 pigs weaned per sow per year while farms with a high culling rate (55.4%) produce 16.4 pigs weaned per sow per year. By current benchmark values, even 17.9 pigs weaned per sow per year is low. The current average pigs weaned per sow per year in the U. S. is 24.2 (PigCHAMP, 2010). This study demonstrated that farms that
have improved longevity are able to wean more pig per sow per year compared to farms that have high turnover rates.

Increasing longevity indirectly through selection on LSY can improve the overall profitability of the breeding herd. Stalder et al. (2000) reported that a sow must stay in the breeding herd through at least parity 3 in order to pay for herself (i.e. initial cost, cost of isolation and acclimation, etc.). These findings were based on a net present value analysis. Sows retained in the herd for additional parities begin to earn a profit for the swine operation. Rodriguez-Zas et al. (2003) showed that genetic lines where sows had the highest average parity at culling also had the highest net present value per sow. These two studies are in agreement that the longer the sows is in the herd, the more revenue she can bring to the operation.

**Post-weaning Growth Traits**

Post-weaning growth traits are indicators of the terminal quality of the gilt. Since sows’ offspring need to be fast growing and have good carcass cutability, having sows with superior maternal and terminal traits is desirable; however, an unfavorable genetic correlation between maternal and terminal traits has often been reported. Holm et al. (2004) published genetic correlations of $-0.03 \pm 0.02$, $-0.00 \pm 0.05$, and $-0.12 \pm 0.06$ between backfat and age at first service, number born alive, and wean to service interval, respectively. The correlations between lean muscle content and age at first service, number born alive, and wean to service interval were $0.02 \pm 0.05$, $-0.12 \pm 0.07$, and $-0.09 \pm 0.10$, respectively. These correlations are based on a Norwegian Landrace sows born between January 1990 and January 2000. Parity and contemporary group were fitted as fixed effects for all traits. Breed was fitted at a fixed effect for number born alive and wean to service interval. Mate type
(multiple or single mating per service) was a fixed effect for age at first service and number born alive. Lactation length and number weaned were fitted as covariates for wean to service interval. Heritabilities were reported as 0.37, 0.10, 0.06, 0.44, and 0.58 for age at first service, number born alive, wean to service interval, backfat, and lean muscle content, respectively.

Chen et al. (2003a) used data on 53,234 Landrace, 251,296 Yorkshire, 75,262 Duroc, and 83,338 Hampshire sows form the National Swine Registry. Heritability estimates for number born alive, litter weaning weight, and number weaned ranged from 0.07 to 0.10, 0.07 to 0.09, and 0.05 to 0.07, respectively. Heritability estimates for lean growth rate, days to 113.5 kg, backfat, and loin muscle are 0.37-0.48, 0.36-0.43, 0.47-0.50, and 0.30-0.35, respectively. Genetic correlations were inconclusive due to large standard errors for number weaned and all four of the growth traits. The same is true for number born alive and litter weaning weight with days to 113.5 kg and loin muscle area. Genetic correlations between number born alive and litter weaning weight and backfat ranged from 0.18 to 0.20 and -0.27 to -0.30. The two traits and lean growth rate have genetic correlations ranging from -0.09 to -0.11 and -0.5 to -0.07.

Young et al (1978) also reported genetic correlations between reproductive and post-weaning, but standard errors were large and the sign of the correlation was inconclusive. This analysis was conducted on 2,095 gilts from the University of Nebraska Gene Pool. Ten Napel and Johnson (1997) attempted to determine genetic correlations between weaning to farrowing interval and average daily gain in test and adjusted back fat depth, but standard errors were large. This study used records on 2,794 Large White and 1,405 Landrace sows on
two farms. The sows were all in parity 3 or younger. The smaller sample sizes result in large standard errors.

**Reproductive Traits**

While there have been few studies examining LSY directly; however, there have been many studies examining the genetic components of other reproductive traits. These studies have focused on traits that have been used in maternal line selection programs. Maternal line selection has typically placed greater emphasis on number born alive (or litter size) and 21day litter weight. This has resulted in the majority of the maternal line research being focused on these two traits.

Chen et al. (2003b) conducted a study on 251,296 Yorkshire, 75,262 Duroc, 83,338 Hampshire, and 53,234 Landrace litters. These records were obtained from the National Swine Registry Swine Testing and Genetic Evaluation System on litter born between 1984 and 1999. Restricted maximum likelihood and the software program REMLF90 was used to estimate the variance components of number born alive (NBA), number weaned (NW), and (L21WT) for each of the four breeds. Contemporary group was the only fixed effect used in the model. Number born alive was adjusted for parity and age at farrowing. Litter weight was adjusted for parity, age at first farrowing, number after transfer, and age at weighing. Number weaned was adjusted for parity and number after transfer. The random effects included in the model were additive genetic effects of animals, additive maternal genetic effects, service sire effect, and permanent environment effect.

The heritability estimates for the traits across breeds were 0.07-0.09 for L21WT, 0.07-0.10 for NBA, and 0.05-0.07 for NW. The genetic correlation estimates between NBA and L21WT ranged from 0.10 to 0.15 across breeds. The range across breeds of the genetic
correlation estimates between NBA and NW was 0.07 to 0.20. Number weaned and L21WT were estimated to be genetic correlated with a range of values from 0.65 to 0.75 across breeds. The variation due to permanent environmental effect was estimated to be between 0.03 and 0.08 percent of the total variation for each of the traits across breeds. The study also examined the effect of eliminating the random additive maternal effect from the model. The Spearman rank correlation between breeding values under both models was 0.93 to 0.98 for each trait across breeds. This suggests that there is little re-ranking depending on whether or not an additive maternal effect was included in the model. This is due to the fact that the maternal effect explained 2% or less of the variation in the traits.

Ferguson et al. (1985) estimated the heritability of NBA, litter live weight at birth (BWLIT), L21WT, sow weight at parturition (WTDAMPAR), and sow weight at weaning (WTDAMWN). The data for this study was obtained from the Western Branch of the Ohio Agricultural Research and Development Center. There were 663 and 460 litter records from Yorkshire and Duroc sows, respectively. Of these litter records, 522 and 359 also included sow weight measurements for Yorkshire and Duroc, respectively. Parity and contemporary group were fitted as fixed effects in the model. Sire and sow were fitted as random effects. Least-squares estimation was used to estimate the genetic parameters for the traits in the study. The heritability estimates for Yorkshires were 0.21, 0.42, 0.19, 0.72, and 0.42 for NBA, BWLIT, L21WT, WTDAMPAR, and WTDAMWN, respectively. For Durocs, the estimates were 0.04, 0.21, 0.25, 0.85, and 0.87 for NBA, BWLIT, L21WT, WTDAMPAR, and WTDAMWN, respectively.

This study estimated the genetic correlations between the traits for the Yorkshire. Genetic correlations between NBA and the other litter traits were estimated to be 0.60 for
BWLIT and 0.36 for L21WT. The genetic correlation estimate between BWLIT and L21WT was 0.43. Number born alive was had a genetic correlation estimate of 0.27 and 0.18 with WTDAMPAR and WTDAMWN, respectively. Litter birth weight was estimated to have genetic correlations of 0.68 and 0.62 with the two dam weight traits. Dam weight at parity and WTDAMWN were estimated to have genetic correlations of 0.60 and 0.29 with L21WT. The genetic correlation between the two sow weight traits was estimated to be 0.93.

Ehlers et al. (2005) estimated the genetic parameters for number born alive, 21-day litter weight, and weaning to oestrus interval using purebred, crossbred, and pooled (purebred and crossbred) data. Data was collected from a swine production system over a 14-year period. The purebred individuals were Yorkshire females. First generation crosses were from the mating of a Yorkshire sow to a Hampshire boar. The F1 females were mated to Landrace males to make a three-way cross. The two-way and three-way crosses were combined together for the crossbred analysis. There were 16,585 litter records from purebred sows and 14,583 records from crossbred sows. The models for all three traits included fixed effects of parity and contemporary group and random effects of animal, service sire, and permanent environment. The model for litter weight also included a fixed effect for type of mating (single or multiple matings), and the model for weaning to oestrus interval included a fixed effect of lactation. When the pooled data was analyzed, breed was included as a fixed effect.

The heritability estimates for NBA was approximately 0.15 regardless of which of the three datasets was used for the estimation. The heritability estimates for L21WT ranged for 0.16-0.20 depending on which data was used. The heritability estimates for W2E were between 0.20 and 0.24 when using purebred, crossbred, or pooled data. The heritabilities
estimated with crossbred data were higher than the heritabilities estimated with purebred data; however, the differences were not large.

The authors also examined the genetic correlations among the three traits. The genetic correlation estimates between NBA and L21WT were 0.17, 0.10 and 0.14 when using purebred, crossbred, and pooled data, respectively. These estimates are directionally the same and similar in magnitude. The genetic correlation estimates between NBA and W2E were -0.03, 0.31 and 0.24 when using purebred, crossbred, and pooled data, respectively. These estimates are not directionally conclusive. The genetic correlation estimates between W2E and L21WT were -0.16, 0.03 and 0.05 when using purebred, crossbred, and pooled data, respectively. These estimates are not directionally conclusive. The disagreement between the estimates when using different datasets suggests that the heritability should be estimated separately for crossbred and purebred populations.

**Adjustment Factors**

Adjustment factors have been developed in order to account for some of the variation in particular traits due to fixed effects, such as contemporary group, parity, breed, etc. Animals in each group are assumed to be more similar than animals in other groups. For example, animals in the same contemporary group are expected to be more similar then animals in other contemporary groups due to the same management being given to each animal within the group.

Young et al. (1976) developed breed adjustment factors for litter size, litter weight, and average pig weight using records on purebred Duroc, Hampshire, and Yorkshire females. These females were mated in such a way to produce all the purebred and two-way cross offspring. A total of 450 litters were used in the analysis. Sows with Yorkshire dams had
1.96 more pigs per litter than sows with Hampshire dams, and 0.77 more pigs per litter than sows with Duroc dams. Sows with Duroc dams had approximately 1.5 kg heavier litter birth weights than sows with either Hampshire or Yorkshire dams. Sows with Yorkshire dams tended to have an average pig weight approximately 0.2 kg less than sows with either Hampshire or Duroc dams. Sows with either Hampshire or Yorkshire dams had over a 6% better survival rate to 42 days than sows with Duroc dams. Differences among sows with sires of different breeds were not as significant as the difference among sows with dams of different breeds.

The effects of season, parity, and sex on pig weights and litter traits were estimated by Schneider et al. (1982). Pigs born in the spring weighed more than pigs born in the fall at birth, 21 days of age and 154 days of age. They also had fewer days to 100 kg. Pigs born from sows in their second or third parity weighed more at each of the three time points than pig born from gilt litters. Litters from older parity sows reached 100 kg quicker than first parity litters. Barrows were heavier than gilts at each of the three weights and reached 100 kg quicker. Litters farrowed in the spring had a greater number born alive, alive at 21 days, and alive at 154 days compared to litters farrowed in the fall. Litters farrowed from second or third parity sows were larger in number compared to litters form gilts.

Yen et al. (1987) estimated the effects of season, parity, and breed on number born alive and 21-day litter weight. Culbertson et al. (1997) also developed adjustment factors for breed and parity for litter traits. The results of these studies are in agreement with the two previous studies. While all of the studies may have come to the same conclusion as far as direction of differences among different factors, the magnitudes of the effects differed. It is important to estimate effects within individual datasets to ensure accurate adjustments. For
this reason, fixed effects are fitted in the models for traits so that values effects are properly determined for the specific study.
CHAPTER 3: GENETIC AND PHENOTYPIC CORRELATIONS BETWEEN MATERNAL AND POST-WEANING TRAITS FROM A COMMERCIAL SWINE BREEDING COMPANY

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Abstract

The purpose of this study was to determine the genetic and phenotypic relationships between litters per sow per year (LSY) and other economically important reproductive and post-weaning traits from a commercial swine breeding company. Determining the genetic and phenotypic correlations among traits can help breeders evaluate the expected impacts their selection decisions have on other economically important production traits that may or may not be included in the selection criteria. This is particularly important when considering reproductive and post-weaning traits because of the undesirable genetic relationships that typically exist between reproductive and post-weaning traits. A total of 32,602 litter records from 7,674 sows were used in this study. The sows were born between 1992 and 2009. Post-weaning traits were recorded on male and female pigs (44,040 records) including sows and their progeny. Data was collected from 4 herds within a single production system. The traits collected included number born alive (NBA), wean to estrus (W2E), adjusted back fat (BF), percent lean (PCL), and days to 100 kg (D100). Litters per sow per year (LSY) was calculated based on recorded information. Number born alive and wean to estrus interval were recorded for every litter. Genetic parameter estimates were calculated using ASREML. The heritability estimates for NBA, LSY, W2E, BF, D100, and PCL were 0.15, 0.03, 0.03, 0.52, 0.33, and 0.36, respectively. The genetic correlation between LSY and W2E was large.
and favorable. The genetic correlations between LSY and the three post-weaning traits (BF, D100, and PCL) have large standard errors and are unclear in direction. Some economically important traits can be favorably changed indirectly with selection on LSY; however, a selection index will be needed to ensure that post-weaning growth traits are not adversely affected by selection for LSY in a maternal line breeding program.

**Key words:** Genetic Correlation, Phenotypic Correlation, Heritability, Litters/sow/year, Swine

**Introduction**

Any day that a breeding female is not lactating or gestating is defined as a non-productive day (Stalder, 2002). Non-productive days are costly to commercial pork operations. If a sow is not gestating or lactating, she is not productive, and therefore, there is no opportunity for her to generate income and be profitable. Non-productive sow day typically occur between weaning and the next successful mating. Non-productive days can cost the producer up to $2.60 per sow per day (Rix and Ketchem, 2009). Reducing non-productive days in a commercial swine operation could greatly impact its profitability. Swine operations would benefit from developing both genetic and management methods to reduce non-productive days. Genetic improvement is a way to permanently improve the number of non-productive days (NPD) in a swine population.

To develop strategies to reduce the number of non-productive days in a sow herd, both indirect and direct traits must be evaluated for incorporation in a selection program. Litters per sow per year (LSY) could potentially be used to reduce the number of non-productive days through indirect selection due to a favorable correlation between LSY and NPD. Litters per sow per year could not only reduce costly non-productive days, but improve
the reproductive efficiency of the sow herd simultaneously. The components of LSY include wean to estrus, non-productive days, farrowing rate, and gestation length. Therefore, selection to improve LSY could potentially have a positive impact on these traits as well. Improving LSY and NPD will improve the throughput or the saleable product (i.e. piglet) per unit of cost (total sow cost), thereby improving production and economic efficiency for individual sows and the operation in its entirety, which could improve profitability for the producer (Stalder et al., 2000).

A 0.1 improvement in LSY could result in 11 fewer non-productive days per sow and almost one more pig produced in a year per sow. At $2.00 a non-productive day and $22.00 per pig, this would result in $52,800 reduced costs and $52,800 increased revenue for a 2,400 sow herd (Rix and Ketchem, 2009 and NSR, 2009).

Before incorporating LSY into a selection program, its relationship with other economically important traits must be determined. The genetic correlations among the traits must be determined in order for the selection index to account for the favorable and unfavorable relationships among economically important traits. The relationships between LSY and growth traits must be determined before it is incorporated into a selection program, since some reproductive traits have been shown to have unfavorable genetic correlations with growth traits (Holm et al., 2004).

The objective of this study was to determine the genetic parameter estimates for LSY and its association with other economically important traits, such as post-weaning growth traits and number born alive. The heritability of LSY and its correlation with other economically important traits can be used to determine the value of adding the trait into a selection program.
Materials and Methods

The data for this study were obtained from an Irish commercial swine breeding company. The data were from nucleus and multiplication herds and were collected on purebred individuals. The dataset contained 32,602 litter records from Landrace and Large White sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. There were 4149 Landrace and 2505 Large White sows with 21,162, and 11,440 litters, respectively. Table 3.1 shows the distribution of litter records by breed. Gilts and sows were mated using artificial insemination procedures with on-farm collected semen. Gilts were bred at 8 months of age, or after their third estrus. Boar exposure was the method of determining estrus and daily heat detection. Litter weaning age for these herds was 27 ± 8 days.

Number born alive (NBA), and wean to estrus (W2E) were collected on every litter. Litters per sow per year (LSY) was calculated based on the records for each sow. The post-weaning traits in the data set were adjusted backfat (adjusted to 100 kg) (BF), days to 100 kg (D100), percent lean (PCL). Table 3.2 shows the distribution of growth records by breed. The post-weaning traits were collected beginning in 1999 resulting in 44,040 records. Before 2004, most of the growth traits were recorded on boars. After 2004, growth records were on equal number of gilts and boars. The average parity at farrowing for the dataset was 3.41. Table 3.3 shows the percent of farrowings at each parity by herd. The average removal parity for the herd was 4.44. Table 3.4 shows the simple means and standard deviations for each trait.
Litters per sow per year was calculated using the formula:

\[
\frac{(\text{number of days gestating})}{115} \frac{\text{(number of days in the breeding herd)}}{365},
\]

where the number of days is the breeding herd was defined as the number of days from the first successful mating of the sow to the weaning date of the last litter recorded for the sow.

A successful mating is defined as a mating that results in the fertilization of eggs and the sow becoming pregnant. Number of days gestating was defined as the sum of each gestation length of the sow. Sows that were active in the herd were also included in the analysis, but not treated as censored data. Previous work has shown that if the number of completed records overwhelms the number of censored records, there is little re-ranking among the breeding value estimations (Engblom et al., 2010).

The heritability of each trait was estimated. The following model was used for the reproductive and lifetime production traits:

\[
y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + X_i \tau_1 + X_i^2 \tau_2 + \delta_l + \varphi_l + \varepsilon
\]

where \( y_{ijkl} \) is the response for sow \( l \) that is breed \( i \), parity \( j \), and in contemporary group \( k \),

\( \mu \) is the overall mean,

\( \alpha_i \) is the effect of breed \( i \),

\( \beta_j \) is the effect of parity \( j \),

\( \gamma_k \) is the effect of contemporary group \( k \),

\( X_i \tau_1 + X_i^2 \tau_2 \) is the effect of age at first successful mating (\( X \)) for sow \( l \),

\( \delta_l \) is the random genetic effect of sow \( l \),
$\varphi_l$ is the permanent environmental effect fitted as an uncorrelated random, and $\epsilon$ is the residual.

Breed was fitted as a fixed effect instead on analyzing breeds separately. When breeds were analyzed separately, there was little change in the results, so the pooled data was used. It was assumed that the variation due to breed of sire was accounted for by the breed of the sow. Contemporary group was defined as the herd, year, and month of farrowing for NBA, and W2E. There were 594 contemporary groups for NBA and W2E with an average of 55 litters per group, and an average of 13 grandsires for the litters in each contemporary group. The contemporary group for the LSY was defined as herd, year, and season (three month period) for the last farrowing of the sow. The contemporary group definition, three month period for the sow’s last farrowing, was used because this contemporary group accounted for more variation among sows compared to a contemporary group for the first farrowing. There were 182 contemporary groups for LSY with an average of 42 sows per group and 13 sire per group. Interactions were assumed to be small and insignificant. The random genetic effect is assumed to be distributed $N(0, \mathbf{A}\sigma^2_G)$ where $\mathbf{A}$ is the relationship matrix. The permanent environmental effect was assumed to be distributed $N(0, \mathbf{I}\sigma^2_P)$. Since the permanent environment effect was fitted as an uncorrelated random, the pedigree information was not used in the estimation of the effect.

The following model was used for the post-weaning traits:

$$y_{ijklmnl} = \mu + \alpha_i + \beta_j + \gamma_k + \tau_m + \delta_n + \varphi_l + \epsilon$$

where $y_{ijklmnl}$ is the response for animal $n$ that is breed $i$, sex $j$, contemporary $k$, feeder type $m$ and litter $l$. 
\( \mu \) is the overall mean,

\( \alpha_i \) is the effect of breed \( i \),

\( \beta_j \) is the effect of sex \( j \),

\( \gamma_k \) is the effect of contemporary group \( k \),

\( \tau_m \) is the effect of feeder type \( m \),

\( \delta_n \) is the random genetic effect of animal \( n \),

\( \varphi_l \) is the common litter effect fitted as an uncorrelated random, and

\( \varepsilon \) is the residual.

Contemporary group was defined as herd, year, and month of birth of the animals.

There were 373 contemporary groups for growth with an average of 118 piglets and 12 sire per group. Feeder type is whether or not the animals were fed with a fire feeder. Pen information was not known for this dataset, and hence, was not included as a fixed effect in the analysis. Interactions were assumed to be small and insignificant. The random genetic effect is assumed to be distributed \( \text{N}(0, \mathbf{A} \sigma_g^2) \) where \( \mathbf{A} \) is the relationship matrix. The common litter effect was assumed to be distributed \( \text{N}(0, \mathbf{I} \sigma_l^2) \). Since the common litter effect was fitted as an uncorrelated random, the pedigree information was not used in the estimation of the effect.

Heritabilities were calculated as sow variance divided by the total variance. Variance components were estimated using ASREML (Gilmour et al., 2006). Convergence to the same parameters was validated with multiple starting points. Correlations were calculated using the covariance between the two traits and the variances of the two traits. Genetic correlations were calculated using the covariance between the genetic components of each trait, and phenotypic correlation calculations used the phenotypic covariance between the traits. The
standard errors for the heritabilities and correlations were calculated appropriately for the quotient of two random variables (Lynch and Walsh, 1998).

**Results**

All fixed effects in the model were significant (P<0.05) for all traits. The fixed effect estimations for the post-weaning growth traits and reproductive traits analyzed in this study are in Table 3.5 and 3.6, respectively. The estimations are expressed relative to the first category in each effect. The effect of age at first successful mating was evaluated for all reproductive traits. Results of these analysis found that age at first successful mating should be included as a quadratic covariate. There is no biological basis for fitting age at first successful mating as a cubic effect.

The variance components estimates from the models described above are in Table 3.7. The additive genetic variances along with the residual variances are shown for each of the traits analyzed. The variance explained by the permanent environment is shown for NBA and W2E. The proportion of the total variation in NBA explained by the permanent environment was 0.09, and for W2E, the proportion was 0.04. The higher proportion of variation due to permanent environment and the higher proportion of genetic variation for NBA suggests that NBA is more repeatable than W2E.

The variance due to the common litter effect is shown for D100, BF, and PCL. The proportion of the total variation in D100, PCL, and BF due to a common litter effect was 0.12, 0.04, and 0.05, respectively. This suggests that a common environment affects D100 more than PCL and BF.

The heritabilities and standard errors for each of the traits analyzed in this study are in Table 3.8. The heritabilities for BF, D100, and PCL were 0.41, 0.33, and 0.36, respectively.
The heritabilities for LSY, NBA and W2E are 0.03, 0.15, and 0.03, respectively. The genetic and phenotypic correlations among the reproductive and post-weaning growth traits are in Table 3.9. The genetic correlation between LSY and W2E is -0.96 which is favorable. The genetic correlations (±SE) between LSY and the three post-weaning traits are 0.26 (±0.19) D100, -0.16 (±0.14) for PCL, and -0.02 (±0.14) for BF. The genetic correlations between LSY and the post-weaning growth traits have large standard errors resulting in the direction of the correlation being unclear.

**Discussion**

The results of this study show that LSY is heritable and therefore, can be incorporated into a selection program and improved. However, expected progress or improvement in LSY resulting from selection would be slow as is the case when genetically improving other reproductive performance traits through traditional selection methods. The heritabilities estimates in this study agree with heritability estimates reported in earlier studies (Lamberson, 1990; Holm et al., 2004; Hanenberg et al., 2001; Adamec and Johnson, 1997). The proportion of variation due to permanent environment is similar to that found in literature (Hanenberg et al., 2001; Suwanasopee et al., 2005).

Using NPD directly in the analysis would be more difficult due to the nature of the trait. If a sow is not bred when she comes into estrus, she will automatically accumulate 21 more non-productive days due to the biological requirements to complete another estrous cycle. This distorts the distribution of NPD making it right skewed. Litters per sow per year is continuously distributed. Litters per sow per year also incorporates other production measures, such as farrowing interval, and farrowing rate. Improving these traits while improving NPD would increase the overall production efficiency of the operation. One
shortcoming of using LSY in a selection program would be that it is only completed at the end of the productive life of the sow, and therefore, would not be measured early in a sow's life.

For the dataset used in this analysis, the mean LSY was 2.43. This value is approaching the average LSY that can be achieved with a 28 day weaning, but there is still room for improvement. This possible average would be 2.47 assuming that a gestation length of 115 days, and wean to estrus interval of 5 days. This also assumes each sow is successful mated at the first service. The average LSY is calculated as 365 / (115+5+28). The denominator is the farrowing interval for a sow that is successfully mated as soon as she comes into estrus after weaning. This number is divided into 365 to calculate the maximum LSY that could be achieved. This may suggest that the calculation for LSY is biased upwards since an LSY value of 2.43 is only achieved with a near perfect record.

The use of LSY in a selection program depends on how LSY is calculated for each particular system. Systems where gilts are already bred before they are brought into the sow herd do not have additional acclimation days added into the calculation of LSY. The calculation also depends on the productive period used for the calculation. For this study, the productive life of the sow was the date of the first successful mating to the weaning date of the last litter. When LSY is extracted from a herd management software program, the productive period is not uniform for sows that are still active in the herd. For the sows removed from the herd, the period from culling to removal would be included and is presumably not the same for each sow.

Before including LSY in a selection program, its genetic correlations with other economically important traits must be considered. Selection for LSY would result in
improvement for the trait as well as improvement for several other economically important traits; however, selection for LSY would result in undesirable changes in some economically important traits, such as BF, D100, and PCL.

The genetic correlations between LSY and the three post-weaning traits (BF, PCL, and D100) were found to be unfavorable, but with large standard errors. The genetic correlations between the three post-weaning traits are similar to previously reported estimates in the scientific literature (Stewart and Schinckel, 1991). This suggests that the genetic correlation estimations found in this study are within the range reported by other researchers. There have been few genetic correlation estimates among lifetime reproductive traits and post-weaning growth traits. The estimations that have been reported have high standard errors (Holm, et al., 2004; Young et al., 1978; ten Napel and Johnson, 1997). These high standard errors cause the correlation to be indistinguishable from zero.

There were 1,039 sows that were not retained in the herd after their first litter. The average LSY for these sows was 2.52 which is greater than the LSY possible with a 28 day weaning period. This is also greater than the average LSY for the herd. This is a result of the method used to calculate LSY. The method of calculating LSY may present a challenge when attempting to use LSY in a selection program for females who have not had more than one litter. These gilts have not had sufficient time to fully express the phenotype for LSY; therefore the values assigned to these gilts for LSY are not truly representative of their genetic potential.

Litters per sow per year is favorably correlated with W2E. This indicates that W2E can be improved through selection on LSY. The correlation between LSY and W2E may indicate that improving LSY can reduce the non-productive days in the sow herd. The
reduction in non-productive days may result in increased profitability for the swine operation if market prices are favorable.

Implications

This study has demonstrated that LSY has genetic variance and may be improved through traditional selection methods. Selection on LSY can indirectly improve W2E and have no antagonistic relationship with NBA; however, selection on LSY may also result in undesirable changes on post-weaning growth traits. It is important to account for these correlations specific to the herd before considering the incorporation of LSY into a selection program. A selection index must be utilized to ensure that the economically important traits are optimized.

Literature Cited


Table 3.1
Number of litter records by breed from an Irish commercial swine breeding company\(^a\)

<table>
<thead>
<tr>
<th>Herd</th>
<th>Landrace</th>
<th>Yorkshire</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>7,069</td>
<td>7,072</td>
</tr>
<tr>
<td>2</td>
<td>7,710</td>
<td>4,362</td>
<td>12,072</td>
</tr>
<tr>
<td>3</td>
<td>8,894</td>
<td></td>
<td>8,894</td>
</tr>
<tr>
<td>4</td>
<td>4,606</td>
<td>9</td>
<td>4,615</td>
</tr>
<tr>
<td>Total</td>
<td>21,213</td>
<td>14,440</td>
<td>32,653</td>
</tr>
</tbody>
</table>

\(^a\)The data were collected from November 1992 to December 2010.
Table 3.2
Number of growth records by breed from an Irish commercial swine breeding company\(^a\)

<table>
<thead>
<tr>
<th>Herd</th>
<th>Landrace</th>
<th>Yorkshire</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,452</td>
<td></td>
<td>3,452</td>
</tr>
<tr>
<td>2</td>
<td>18,690</td>
<td>12,373</td>
<td>31,063</td>
</tr>
<tr>
<td>3</td>
<td>2,399</td>
<td></td>
<td>2,399</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>7,123</td>
<td>7,126</td>
</tr>
<tr>
<td>Total</td>
<td>24,544</td>
<td>19,496</td>
<td>44,040</td>
</tr>
</tbody>
</table>

\(^a\)The data were collected from 1999 to 2010.
<table>
<thead>
<tr>
<th>Herd</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.8</td>
<td>21.5</td>
<td>18.0</td>
<td>14.3</td>
<td>11.4</td>
<td>8.1</td>
<td>2.5</td>
<td>0.4</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>26.8</td>
<td>21.3</td>
<td>16.4</td>
<td>12.3</td>
<td>9.0</td>
<td>6.3</td>
<td>3.9</td>
<td>2.3</td>
<td>1.0</td>
<td>0.4</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>3</td>
<td>18.0</td>
<td>15.7</td>
<td>14.3</td>
<td>12.6</td>
<td>10.8</td>
<td>9.1</td>
<td>7.5</td>
<td>5.8</td>
<td>3.9</td>
<td>1.1</td>
<td>0.5</td>
<td>0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>4</td>
<td>23.7</td>
<td>19.3</td>
<td>15.8</td>
<td>12.8</td>
<td>9.9</td>
<td>7.2</td>
<td>4.9</td>
<td>2.9</td>
<td>1.7</td>
<td>1.1</td>
<td>0.4</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23.3</td>
<td>19.5</td>
<td>16.1</td>
<td>12.9</td>
<td>10.1</td>
<td>7.6</td>
<td>4.7</td>
<td>2.9</td>
<td>1.7</td>
<td>0.7</td>
<td>0.2</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

*The data were collected from November 1992 to December 2010.*
Table 3.4  
Reproductive and post-weaning trait simple means (±SD) from an Irish commercial swine breeding company\(^a\)

<table>
<thead>
<tr>
<th>Trait(^b)</th>
<th>Mean (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number born alive</td>
<td>11.6 (±3.2)</td>
</tr>
<tr>
<td>Litters per sow per year</td>
<td>2.4 (±0.2)</td>
</tr>
<tr>
<td>Wean to estrus (d)</td>
<td>6.4 (±4.5)</td>
</tr>
<tr>
<td>Adjusted backfat (mm)</td>
<td>10.2 (±2.1)</td>
</tr>
<tr>
<td>Days to 100 kg</td>
<td>162.8 (±15.1)</td>
</tr>
<tr>
<td>Percent lean</td>
<td>60.3 (±2.4)</td>
</tr>
</tbody>
</table>

\(^a\)The dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. There were 44,040 growth records in that data set.

\(^b\)Number born alive and wean to estrus were collected on every litter. Litters per sow per year was calculated as described in the text. Adjusted backfat (adjusted to 100 kg), days to 100 kg, and percent lean were calculated post-weaning.
Table 3.5
Fire feeder, breed, and sex fixed effect estimations for post-weaning growth traits (days to 100 kg, adjusted backfat, and percent lean) from an Irish commercial swine breeding company<sup>a</sup>.

<table>
<thead>
<tr>
<th>Effect</th>
<th>D100</th>
<th>BF</th>
<th>PCL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire Feeder</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>1.021</td>
<td>0.73</td>
<td>-0.38</td>
</tr>
<tr>
<td><strong>Breed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large White</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Landrace</td>
<td>-2.23</td>
<td>0.24</td>
<td>-0.34</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Male</td>
<td>-6.02</td>
<td>-0.84</td>
<td>0.36</td>
</tr>
</tbody>
</table>

<sup>a</sup>There were 44,040 growth records in the data set. Fixed effects were estimated using ASREML and a model as described in the text. Adjusted backfat (BF) (adjusted to 100 kg), days to 100 kg (D100), and percent lean (PCL) were calculated post-weaning.
Table 3.6
Breed and parity fixed effect estimations for reproductive traits (number born alive, wean to estrus interval, and litters per sow per year) from an Irish commercial swine breeding company

<table>
<thead>
<tr>
<th>Effect</th>
<th>NBA</th>
<th>W2E</th>
<th>LSY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large White</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Landrace</td>
<td>0.46</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.71</td>
<td>-1.3</td>
<td>-0.10</td>
</tr>
<tr>
<td>3</td>
<td>1.20</td>
<td>-1.45</td>
<td>-0.10</td>
</tr>
<tr>
<td>4</td>
<td>1.17</td>
<td>-1.59</td>
<td>-0.10</td>
</tr>
<tr>
<td>5</td>
<td>0.91</td>
<td>-1.48</td>
<td>-0.10</td>
</tr>
<tr>
<td>6</td>
<td>0.70</td>
<td>-1.24</td>
<td>-0.09</td>
</tr>
<tr>
<td>7</td>
<td>0.28</td>
<td>-1.17</td>
<td>-0.10</td>
</tr>
<tr>
<td>8</td>
<td>-0.17</td>
<td>-0.97</td>
<td>-0.08</td>
</tr>
<tr>
<td>9</td>
<td>-0.62</td>
<td>-0.90</td>
<td>-0.08</td>
</tr>
<tr>
<td>10</td>
<td>-1.31</td>
<td>-0.43</td>
<td>-0.07</td>
</tr>
<tr>
<td>11</td>
<td>-1.26</td>
<td>-0.28</td>
<td>-0.08</td>
</tr>
<tr>
<td>12</td>
<td>-1.96</td>
<td>-0.50</td>
<td>-0.06</td>
</tr>
<tr>
<td>13</td>
<td>-0.58</td>
<td>-0.66</td>
<td>-0.09</td>
</tr>
</tbody>
</table>

*The dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. There were 44,040 growth records in the data set. Fixed effect estimations were calculated using ASREML and models as described in the text. Number born alive (NBA) and wean to estrus (W2E) were collected on every litter. Litters per sow per year was calculated as described in the text.*
Table 3.7
Estimated variance components (percent of total variance) for reproductive and post-weaning traits from an Irish commercial swine breeding companya.

<table>
<thead>
<tr>
<th>Traitb</th>
<th>Additive Genetic</th>
<th>Permanent Environment</th>
<th>Common Liter</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number born alive</td>
<td>1.39</td>
<td>0.81 (0.09)</td>
<td>-</td>
<td>7.25</td>
</tr>
<tr>
<td>Litters per sow per year</td>
<td>0.0008</td>
<td>-</td>
<td>-</td>
<td>0.025</td>
</tr>
<tr>
<td>Wean to estrus (d)</td>
<td>0.64</td>
<td>0.73 (0.04)</td>
<td>-</td>
<td>18.22</td>
</tr>
<tr>
<td>Adjusted backfat (mm)</td>
<td>1.42</td>
<td>-</td>
<td>0.16 (0.05)</td>
<td>1.89</td>
</tr>
<tr>
<td>Days to 100 kg</td>
<td>46.05</td>
<td>-</td>
<td>20.01 (0.12)</td>
<td>96.77</td>
</tr>
<tr>
<td>Percent lean</td>
<td>1.83</td>
<td>-</td>
<td>0.22 (0.04)</td>
<td>2.98</td>
</tr>
</tbody>
</table>

aThe dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. There were 44,040 growth records in the data set. Variance component estimations were calculated using ASREML and models as described in the text.

bNumber born alive and wean to estrus were collected on every litter. Litters per sow per year was calculated as described in the text. Adjusted backfat (adjusted to 100 kg), days to 100 kg, and percent lean were calculated post-weaning.
<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability (±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number born alive</td>
<td>0.15 (±0.02)</td>
</tr>
<tr>
<td>Litters per sow per year</td>
<td>0.03 (±0.02)</td>
</tr>
<tr>
<td>Wean to estrus (d)</td>
<td>0.03 (±0.01)</td>
</tr>
<tr>
<td>Adjusted backfat (mm)</td>
<td>0.41 (±0.01)</td>
</tr>
<tr>
<td>Days to 100 kg</td>
<td>0.28 (±0.01)</td>
</tr>
<tr>
<td>Percent lean</td>
<td>0.36 (±0.01)</td>
</tr>
</tbody>
</table>

The dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. There were 44,040 growth records in the data set. Heritabilities were calculated using ASREML and models as described in the text.

Number born alive and wean to estrus were collected on every litter. Litters per sow per year was calculated as described in the text. Adjusted backfat (adjusted to 100 kg), days to 100 kg, and percent lean were calculated post-weaning.
Table 3.9
Genetic (above the diagonal) and phenotypic correlations (below the diagonal) (±SE) for reproductive and post-weaning traits estimated from an Irish commercial swine breeding company

<table>
<thead>
<tr>
<th></th>
<th>LSY</th>
<th>D100</th>
<th>PCL</th>
<th>BF</th>
<th>NBA</th>
<th>W2E</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSY</td>
<td>-</td>
<td>0.26 (0.19)</td>
<td>-0.16 (0.14)</td>
<td>0.02 (0.14)</td>
<td>-0.21 (0.28)</td>
<td>-0.96 (0.04)</td>
</tr>
<tr>
<td>D100</td>
<td>-0.01 (0.03)</td>
<td>-</td>
<td>0.33 (0.03)</td>
<td>-0.03 (0.04)</td>
<td>0.33 (0.09)</td>
<td>-0.27 (0.63)</td>
</tr>
<tr>
<td>PCL</td>
<td>0.03 (0.03)</td>
<td>0.21 (0.01)</td>
<td>-</td>
<td>-0.94 (0.01)</td>
<td>-0.02 (0.09)</td>
<td>0.64 (1.79)</td>
</tr>
<tr>
<td>BF</td>
<td>-0.03 (0.03)</td>
<td>-0.01 (0.01)</td>
<td>-0.74 (0.00)</td>
<td>-</td>
<td>0.03 (0.09)</td>
<td>-0.31 (0.97)</td>
</tr>
<tr>
<td>NBA</td>
<td>0.00 (0.01)</td>
<td>-0.01 (0.01)</td>
<td>-0.02 (0.02)</td>
<td>-0.01 (0.01)</td>
<td>-</td>
<td>-0.64 (0.31)</td>
</tr>
<tr>
<td>W2E</td>
<td>-0.25 (0.01)</td>
<td>0.01 (0.01)</td>
<td>0.01 (0.01)</td>
<td>0.00 (0.01)</td>
<td>-0.04 (0.00)</td>
<td>-</td>
</tr>
</tbody>
</table>

The dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. There were 44,040 growth records in the dataset. Correlations were calculated using ASREML and models as described in the text.

Number born alive (NBA) and wean to estrus (W2E) were collected on every litter. Litters per sow per year (LSY) was calculated as described in the text. Adjusted backfat (adjusted to 100 kg) (BF), days to 100 kg (D100), and percent lean (PCL) were calculated post-weaning.
The purpose of this study was to determine the relationship of individual sire estimated breeding values (EBV) for litters/sow/year (LSY) with sire progeny means for farrowing rate, removal parity, and lifetime born alive. A data set from a production system consisting of records for 48,662 sows from 9 herds was used for the analyses. Landrace, Large White, and F₁ (Y×L or L×Y) crossbred females were included in the analyses. Breed, contemporary group of last litter, and parity of last litter were fitted as fixed effects for LSY. Age at first service was included as a quadratic covariate. Animal was fitted as a random genetic effect. Breeding values for LSY were estimated in ASREML using the model described above. The heritability estimate for LSY was 0.11. Sire progeny (daughter) mean farrowing rate was calculated as total number of services on all daughters that were bred divided by the total litters farrowed from the sire’s daughters. Similar calculations were done for daughter average removal parity, and average lifetime born alive. The Spearman rank correlation between the LSY BV and the daughter average farrowing rate for each sire was calculated using SAS software. When all sires with 10 or more daughters were included in the analysis, the Spearman rank correlations between the sire’s LSY EBV and the daughter means for farrowing rate, removal parity, and lifetime born alive were 0.49, 0.23, and 0.25 (P<0.01). The LSY EBV was favorably correlated with daughter means for all three traits.
This provides evidence that selecting sires with high estimated breeding values for LSY to improve the LSY could also improve the herd farrowing rate, removal parity, and lifetime born alive. Sires ranked in the top 25% for LSY estimated breeding values had a 15.3% higher daughter average farrowing rate compared to sires in the bottom 25%. Daughters from the top sire had a one parity greater average removal parity than daughters from the other sire group. This extra litter corresponded to an average of 8.9 more pigs produced in a sow’s lifetime.

**Key words:** breeding value, litters per sow per year, farrowing rate

**Introduction**

The overall annual farrowing rate (FR) of a herd is calculated as the total number of services during a year divided by the total number of litters farrowed during the year (Stalder, 2002). There are many factors that influence the FR of the herd, including service sire fertility, breeding management, and sow reproductive performance. Sows that successfully farrow a litter after only one service can improve the efficiency and production of the breeding herd, and thus, increase the profit for the swine operation. If a sow does not conceive or is not successfully mated on the first service, a producer must wait 21 days before she will normally be in estrous again. This would mean that the sow would accumulate another 21 non-productive days, or days when she is not gestating or lactating (Stalder, 2002). According to Rix and Kechthum (2009), a non-productive day costs pork producers between $1.60 and $2.60 per sow per day, and the average number of non-productive days per sow per year is 35. Assuming a cost of $2.00 per non-productive day, an unsuccessful service and the accumulation of 21 non-productive days would cost a producer
$42.00 for that single unsuccessful event. It is easy to see how a breeding herd can accumulate a substantial number of non-productive days.

Improving FR could facilitate the reduction in non-productive days of the herd. This could result in a substantial cost savings for the operation. Since FR is a component of litters per sow per year (LSY), examining the relationship between LSY and FR could result in the development of a method to reduce the number of non-productive days in a breeding herd. Previous results have shown a favorable correlation between LSY and FR (Koketsu, 2005). Koketsu (2005) also reported that a 0.1 increase in LSY can result in 11 fewer annual non-productive days per sow.

The removal parity and lifetime born alive are ways to measure sow longevity. Sow longevity can be defined as the length of the productive life or the lifetime production of the sow. Improving sow longevity increases overall herd profitability. Sows that remain in the herd for multiple parities have more opportunity to be sufficiently productive to offset the initial replacement cost and gilt development costs associated with each sow (Stalder, 2002). If sows are still producing at desirable levels, the improved genetics of the gilts will not offset their initial replacement and gilt development costs (Abell et al., 2010).

The objective of this study was to determine the relationship between a sire’s LSY EBV and his progeny mean for FR, removal parity, and lifetime born alive. This study also estimated the heritability of LSY and the potential for incorporating LSY into a selection program. The genetic correlation between LSY and number born alive (NBA) was also examined in order to determine if an unfavorable relationship existed between LSY and an economically important trait.
Materials and Methods

The data used in this analysis was obtained from 9 herds from a single production system. Data was collected from October 1993 to June 2009. Pedigree information was also collected for this time period. A total of 231,858 records from 48,622 sows were used in the analysis. Sows were either Landrace (17,834 sows), Large White (13,836 sows), or F₁ (Y×L or L×Y) crossbred (16,992 sows) females. In the dataset, 80,806 records were from the Landrace sows, 68,499 records were from the Large White sows, and 82,553 records were from the crossbred sows. Table 4.1 shows the distribution of breeds by herd. The average parity at farrowing was 3.80. Table 4.2 shows the distribution of parity at farrowing for each herd. The average removal parity was 5.30.

Gilts and sows were mated using artificial insemination procedures with on-farm collected semen. Gilts were bred after 7 months of age, or at their third estrus. Estrus was determined by boar exposure and heat detection was done daily using a boar. Number born alive was recorded for each litter. Lifetime born alive (LTBA) was calculated as the sum of number born alive for each litter across all litters produced by individual sows. Farrowing rate for each sow was calculated as the number of farrowings divided by the number of services on the sow. Litters per sow per year was extracted from PigCHAMP™ herd management software which uses the following formula:

\[
\text{(number of days gestating)/115} \\
\text{(number of days in the breeding herd)/365}.
\]

Sows that were active in the herd were also included in the analysis, but not treated as censored data. Previous work has shown that if the number of completed records overwhelms the number of censored records, there is little re-ranking among the breeding value
estimations (Engblom et al., 2010). Table 4.3 shows the simple means and standard deviations of each trait.

Wean to estrus values over 25 days were truncated to 25. Since the estrous cycle is only 21 days long, a sow should come in to heat by 25 days after weaning (ten Napel and Johnson, 1997). Wean to estrus values equal to zero were assigned to 15 days. Age at first service was recorded for each female. The average age of replacement gilts at first service was 257 days. Age at first service was truncated at 130 and 398 days of age, representing two standard deviations from the mean. Records where the NBA was 0 or greater than 25 were considered to be incorrect and were deleted. Data edits are similar to those found in Tummaruk et al. (2001).

The heritability of each of the traits was estimated. The following model was used for the estimation of the heritabilities:

\[ y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + X_{il} \tau_1 + X_{i}^2 \tau_2 + \delta_l + \varphi_l + \varepsilon \]

where \( y_{ijkl} \) is the response for sow \( l \) that is breed \( i \), parity \( j \), and in contemporary group \( k \),

\( \mu \) is the overall mean,

\( \alpha_i \) is the effect of breed \( i \),

\( \beta_j \) is the effect of parity \( j \),

\( \gamma_k \) is the effect of contemporary group \( k \),

\( X_{il} \tau_1 + X_{i}^2 \tau_2 \) is the effect of age at first service mating \( (X) \) for sow \( l \),

\( \delta_l \) is the random effect of sow \( l \),
\( \varphi_t \) is the permanent environmental effect fitted as an uncorrelated random, and \( \epsilon \) is the residual.

Breed was fitted as a fixed effect instead on analyzing breeds separately. When breeds were analyzed separately, there was little change in the results, so the pooled data was used. It was assumed that the variation due to breed of sire was accounted for by the breed of the sow. Contemporary group was defined as the herd, year, and month of the farrowing for NBA. There were 1,055 contemporary groups for NBA with an average of 220 litters and 87 grandsires per group. For LTBA, FR, and LSY, contemporary group was defined as the herd, year, and season (4-month period) for the last litter of the sow. The 4-month periods (season) included the following month groupings within each year: March-June, July-October, and November-February. The farrowing rate by month was calculated to determine the seasons. March through June saw almost a 10% decrease in the farrowing rate compared to the other months. This resulted in 274 contemporary groups for LSY, LTBA, and FR with an average of 846 sows per group and 93 sires per group.

Permanent environment was only fitted for NBA, because NBA was the only trait with repeated records in this study. The random genetic effects were assumed to be normally distributed with mean 0 and variance \( A \sigma^2_g \), where \( A \) is the relationship matrix for the population. The permanent environmental effects were assumed to be independent and identically normally distributed with mean 0 and variance \( \sigma^2_p \). The relationships among the animals were not included in the estimation of the permanent environment effect. The software used to estimate the heritabilities and correlations between the traits was ASREML (Gilmour et al., 2006). Convergence to the same parameters was verified with multiple starting points. Correlations were calculated using the covariance between the two traits and
the variances of the two traits. Genetic correlations were calculated using the covariance between the genetic components of each trait, and phenotypic correlation calculations used the phenotypic covariance between the traits. The correlations and standard errors are calculated as described in Lynch and Walsh (1998). This model was also used to estimate the LSY breeding values of the sires.

A total of 251,992 service records were collected on 47,898 sows. Service records were collected from 1998 to 2008. Many of the sows with service record information were included in the litter records described previously. Sire progeny (daughter) mean farrowing rates were calculated by the total number of litters from all daughters divided by the total number of services on all daughters. The average daughter removal parity for each sire was calculated as the average removal parity for all of his daughters. A similar calculation was done for lifetime born alive. The average number of daughters per sire was 10. The daughter mean farrowing rate for the sires was 82.9% ± 16%. The maximum was 100%, and the minimum was 5.3%. The average progeny mean for removal rate was 5.25 ± 2.54 with a minimum of 1 and a maximum of 12. The average daughter lifetime born alive per sire was 50.4 ± 27.1 pigs with a range from 0 to 155 pigs. The correlation between sire progeny means and LSY BV was estimated using the CORRELATION procedure in SAS 9.2 (SAS Institute, 2004). Both the Pearson and Spearman Rank correlations were estimated. The UNIVARIATE procedure was used to determine range for each percentile of the LSY EBVs. The average daughter farrowing rate, EBV values using the MEANS procedure.

Results

All fixed effects were significant (P<0.05). Table 4.4 shows the estimations of the fixed effects. Table 4.5 shows the heritabilities and genetic and phenotypic correlations of
NBA, LTBA, LSY, and FR. The heritabilities for NBA, LTBA, and LSY are 0.02, 0.11, and 0.11, respectively. The genetic correlation between LSY and NBA is indistinguishable from zero. This correlation would indicate that selecting for LSY would not impact the potential to simultaneously improve NBA. The genetic correlation between LSY and LTBA is 0.16, suggesting a positive genetic relationship between LSY and LTBA. These genetic correlations would suggest that there is no adverse relationship between LSY and the other two traits, NBA and LTBA. The genetic correlation between LSY and FR was 0.63 suggesting a positive genetic relationship between LSY and FR.

The Pearson and Spearman rank correlations between LSY EBVs and sire progeny means for farrowing rate, removal parity, and lifetime born alive are in Table 4.6. These correlations suggest a favorable relationship between LSY EBVs and daughter averages for all three traits. The correlation with the greatest magnitude was between LSY and farrowing rate. Correlations between LSY and removal parity and lifetime born alive were similar in magnitude.

Figures 4.1 and 4.2 show the average daughter farrowing rate, removal parity, and lifetime born alive for sires ranking in each percentile for LSY BV for all sires and sires with 10 or more daughters. It is clear that daughter farrowing rate tended to improve as the LSY EBV ranking improved. The sires in the top 25% according to their LSY EBVs had an average daughter farrowing rate of 89.0%, while sires in the bottom 25% had an average daughter farrowing rate of only 74.3%. There is a clear division between the daughter means for farrowing rates at the 45th percentile. At this point, the daughter means for farrowing rate between adjacent percentiles increases over 3 percent. When only sires with 10 or more daughters were included in the rankings, the top 25% had an average farrowing rate of 87.0%
and the bottom 25% had an average of 75.0%. With this group of sires, the division occurs at the 50\textsuperscript{th} percentile. These divisions suggest that independent culling levels for LSY could be incorporated to help improve the farrowing rate of the herd.

Sires in the top 25% for LSY BVs have a 1 parity increase in average daughter removal parity compared to sires in the bottom 25%. The differences between the average for sires in the top 25% and the bottom 25% was 8.9 piglets. It is clear that sires ranked low for LSY EBVs produced daughters with lower removal parities and lower lifetime born alive.

\textbf{Discussion}

The results of this study indicate that LSY can be incorporated into a selection program to improve the efficiency of the breeding herd. The heritability of LSY was estimated to be 0.11; with a standard error of 0.01, this estimate is significantly different from zero. The estimate of the genetic correlation between LSY and LTBA was also different from zero. The heritabilities estimates for NBA and FR in this study agree with heritability estimates reported in earlier studies (Lamberson, 1990; Hanenberg et al., 2001; Adamec and Johnson, 1997). This positive association between LSY and LTBA may mean that selection for improved LSY can increase number of pigs born during a sow’s lifetime through indirect selection. This favorable relationship may improve the overall production efficiency of the herd if sows are able to produce more litters in a year and more piglets in a lifetime. There was not a significant genetic correlation between LSY and NBA suggesting there is not an antagonistic relationship between LSY and NBA. The genetic correlation between LSY and FR is significantly different from zero, suggesting that selection for LSY can indirectly improve FR.
The average LSY for this dataset was 2.12, with a standard deviation of 0.40. Assuming an average gestation length of 115 days, a 21 day weaning management, and a 5 day weaning to estrus interval, 2.59 is the average LSY that could be achieved with a successful first service after weaning. The shortest farrowing interval possible would be 141 days. The average LSY is calculated by 365 / 141. Since the average LSY for the herd is 0.47 away from the expected average under a perfect production system, there is room for improvement and efficient, successful selection is possible. There is also sufficient variation for improvement to be made through selection.

A 0.1 improvement in LSY could result in 11 fewer non-productive days per sow and almost a one pig increase produced in a year per sow. At $2.00 a non-productive day and $22.00 per pig, this would result in $52,800 reduced costs and $52,800 increased revenue for a 2,400 sow herd (Rix and Ketchem, 2009 and NSR, 2009).

Since LSY is not correlated with NBA, its correlation with LTBA may be the result of an increased productive life of sows with higher LSY. Improving the productive lifetime of a sow can improve the profitability of the swine operation. Sows must remain in the herd for at least 3 parities in order to produce enough piglets to offset the initial cost of the purchase of a replacement gilt and the costs associated with gilt development (Stalder et al., 2000).

Previous studies have shown that LSY is favorably related with other economically important traits. Koketsu (2005) found that with every 0.1 increase in LSY pigs weaned per sow per year will increase by 0.9. This would result in a 0.74 increase in pigs weaned per mated female per year for high performing sows and 0.63 pigs in ordinary farms. Sasaki and Koketsu (2008) showed that LSY is positively correlated with the proportion of sow
classified as high longevity (removal after parity 5) and high efficiency sows, and LSY is negatively correlated with the proportion of sows classified as low longevity (removed before parity 5).

From this study, there is strong evidence for a favorable relationship between LSY and farrowing rate, removal parity, and lifetime born alive. The genetic correlations estimates between LSY and LTBA and FR suggest that the correlations between LSY EBVs and sire progeny means for the traits are not completely due to environmental correlations. Selection for LSY could result in the indirect improvement of each trait, since sires with higher LSY EBVs tended to have higher progeny means for farrowing rate, removal parity, and lifetime born alive. Improving the farrowing rate in the herd can improve the profitability of the herd by reducing the number of non-productive days associated with unsuccessful services, and the labor costs associated with multiple services. Improving removal parity and lifetime born alive can improve sow longevity. Increasing the longevity of the herd will improve the profitability of the operation by reducing gilt replacement costs and increasing the revenue obtained from each sow.

Implications

The results of this study suggest that there is potential for incorporating LSY into a selection program. By including LSY as part of the selection criterion, the LTBA may be indirectly improved as well as the farrowing rate, removal parity, and lifetime born alive of the herd. The positive genetic correlation between LTBA and LSY may be a result of the improved longevity of sows with greater LSY compared to sows with lower LSY. More research is needed to fully understand this relationship. The relationships between LSY and
farrowing rate, removal parity, and lifetime born alive are strongly supported by the correlations between the sire progeny means for each trait and the sire LSY BVs.

**Literature Cited**


Table 4.1
Number of litter records by breed from a Thai swine production system\textsuperscript{a}

<table>
<thead>
<tr>
<th>Herd</th>
<th>Landrace</th>
<th>Yorkshire</th>
<th>Crossbred</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18,580</td>
<td>13,917</td>
<td></td>
<td>32,497</td>
</tr>
<tr>
<td>2</td>
<td>14,347</td>
<td>10,864</td>
<td></td>
<td>25,211</td>
</tr>
<tr>
<td>3</td>
<td>29,645</td>
<td>27,430</td>
<td>601</td>
<td>57,676</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>36,681</td>
<td>36,681</td>
</tr>
<tr>
<td>5</td>
<td>18,234</td>
<td>16,285</td>
<td></td>
<td>34,519</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>14,429</td>
<td>14,429</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>13,802</td>
<td>13,802</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td></td>
<td>9,193</td>
<td>9,196</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>7,847</td>
<td>7,847</td>
</tr>
<tr>
<td>Total</td>
<td>80,806</td>
<td>68,499</td>
<td>82,553</td>
<td>231,858</td>
</tr>
</tbody>
</table>

\textsuperscript{a}The data were collected from October 1993 to June 2009.
Table 4.2
Percentage of farrowings by parity and herd from a Thai swine production system\textsuperscript{a}

<table>
<thead>
<tr>
<th>Herd</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.8</td>
<td>16.7</td>
<td>14.5</td>
<td>12.6</td>
<td>10.6</td>
<td>8.8</td>
<td>7.1</td>
<td>5.5</td>
<td>3.5</td>
<td>0.9</td>
<td>0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>2</td>
<td>19.7</td>
<td>17.4</td>
<td>14.9</td>
<td>12.4</td>
<td>10.6</td>
<td>8.6</td>
<td>6.9</td>
<td>5.4</td>
<td>3.5</td>
<td>0.6</td>
<td>0.1</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>19.9</td>
<td>17.0</td>
<td>14.9</td>
<td>12.9</td>
<td>10.8</td>
<td>9.0</td>
<td>7.3</td>
<td>5.4</td>
<td>2.6</td>
<td>0.2</td>
<td>&lt;0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>21.1</td>
<td>17.5</td>
<td>15.0</td>
<td>12.9</td>
<td>10.7</td>
<td>8.8</td>
<td>6.9</td>
<td>4.5</td>
<td>1.9</td>
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<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>21.0</td>
<td>17.9</td>
<td>15.6</td>
<td>13.2</td>
<td>11.1</td>
<td>9.1</td>
<td>6.7</td>
<td>3.8</td>
<td>1.4</td>
<td>0.3</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16.6</td>
<td>14.4</td>
<td>12.8</td>
<td>11.2</td>
<td>9.4</td>
<td>9.0</td>
<td>7.2</td>
<td>6.2</td>
<td>5.0</td>
<td>4.1</td>
<td>3.0</td>
<td>1.0</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>7</td>
<td>21.5</td>
<td>17.4</td>
<td>14.7</td>
<td>12.5</td>
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<td>8.7</td>
<td>6.9</td>
<td>4.8</td>
<td>2.2</td>
<td>0.6</td>
<td>0.1</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>18.6</td>
<td>15.4</td>
<td>13.7</td>
<td>12.0</td>
<td>10.6</td>
<td>9.3</td>
<td>7.7</td>
<td>6.0</td>
<td>4.2</td>
<td>2.2</td>
<td>0.3</td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>22.7</td>
<td>18.7</td>
<td>16.2</td>
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<td>2.1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Total</td>
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<td>10.7</td>
<td>8.9</td>
<td>7.0</td>
<td>5.0</td>
<td>2.7</td>
<td>0.7</td>
<td>0.2</td>
<td>0.1</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

\textsuperscript{a}The data were collected from October 1992 to June 2009.
Table 4.3
Reproductive trait simple means (±SD) from a Thai swine production system\textsuperscript{a}

<table>
<thead>
<tr>
<th>Trait\textsuperscript{b}</th>
<th>Mean (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number born alive</td>
<td>9.8 (±2.7)</td>
</tr>
<tr>
<td>Lifetime born alive</td>
<td>48.4 (±30.5)</td>
</tr>
<tr>
<td>Litters per sow per year</td>
<td>2.12 (±0.40)</td>
</tr>
<tr>
<td>Farrowing rate</td>
<td>0.84 (±0.18)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}The dataset contained 231,858 litter records of Landrace, Large White, and F1 cross sows from October 1993 to June 2009. A total of 48,662 sows from 9 herds in a single production system were used in the analysis. Service records were collected from 1996 to 2008.

\textsuperscript{b}Number born alive was collected on every litter. Lifetime born alive was calculated as the sum of each number born alive record for the sow. Litters per sow per year was extracted from PigCHAMP\textsuperscript{TM}. Farrowing rate was calculated as the number of farrowings for the sow divided by the number of services for the sow.
Table 4.4
Breed and parity fixed effect estimations for reproductive traits (number born alive, wean to estrus interval, and litters per sow per year) from a Thai swine production system

<table>
<thead>
<tr>
<th>Effect</th>
<th>NBA</th>
<th>LTBA</th>
<th>FR</th>
<th>LSY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large White</td>
<td>0.00</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Landrace</td>
<td>0.02</td>
<td>-0.8</td>
<td>0.00</td>
<td>-0.03</td>
</tr>
<tr>
<td>F1 Cross</td>
<td>0.51</td>
<td>3.9</td>
<td>-0.02</td>
<td>-0.01</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
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<td>9.4</td>
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<td>0.13</td>
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<td>0.02</td>
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<tr>
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<td>39.2</td>
<td>0.05</td>
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</tr>
<tr>
<td>6</td>
<td>0.65</td>
<td>48.9</td>
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<td>90.2</td>
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</tbody>
</table>

*The dataset contained 231,858 litter records of Landrace, Large White, and F1 cross sows from October 1993 to June 2009. A total of 48,662 sows from 9 herds in a single production system were used in the analysis. Service records were collected from 1996 to 2008. Number born alive (NBA) was collected on every litter. Lifetime born alive (LTBA) was calculated as the sum of each NBA record for the sow. Litters per sow per year (LSY) was extracted from PigCHAMP™. Farrowing rate (FR) was calculated as the number of farrowings for the sow divided by the number of services for the sow. Fixed effects were estimated using a model as described in the text.*
Table 4.5
Heritabilities (on diagonal), genetic (below the diagonal) correlations, and phenotypic correlations (above the diagonal) (±SE) for reproductive traits estimated from a Thai swine production system

<table>
<thead>
<tr>
<th></th>
<th>LSY</th>
<th>NBA</th>
<th>LTBA</th>
<th>FR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSY</td>
<td>0.11 (0.01)</td>
<td>-0.03 (0.005)</td>
<td>0.01 (0.01)</td>
<td>0.54 (0.004)</td>
</tr>
<tr>
<td>NBA</td>
<td>-0.03 (0.05)</td>
<td>0.02 (0.002)</td>
<td>0.59 (0.003)</td>
<td>-0.05 (0.005)</td>
</tr>
<tr>
<td>LTBA</td>
<td>0.25 (0.05)</td>
<td>0.999 (0.005)</td>
<td>0.12 (0.01)</td>
<td>-0.00 (0.005)</td>
</tr>
<tr>
<td>FR</td>
<td>0.63 (0.06)</td>
<td>0.04 (0.09)</td>
<td>0.21 (0.08)</td>
<td>0.03 (0.01)</td>
</tr>
</tbody>
</table>

*a*The dataset contained 231,858 litter records of Landrace, Large White, and F1 cross sows from October 1993 to June 2009. A total of 48,662 sows from 9 herds in a single production system were used in the analysis. Service records were collected from 1996 to 2008.

*b*Number born alive (NBA) was collected on every litter. Lifetime born alive (LTBA) was calculated as the sum of each NBA record for the sow. Litters per sow per year (LSY) was extracted from PigCHAMP™. Farrowing rate (FR) was calculated as the number of farrowings for the sow divided by the number of services for the sow. Heritabilities and correlations were estimated using a model as described in the text.
Table 4.6
Pearson and Spearman Rank correlations between litters per sow per year estimated breeding values and sire progeny means for farrowing rate, removal parity, and lifetime born alive estimated from Thai swine production system

<table>
<thead>
<tr>
<th></th>
<th>Pearson</th>
<th>Spearman Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farrowing Rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Sires (n=4,115)</td>
<td>0.28</td>
<td>0.38</td>
</tr>
<tr>
<td>Sires with ≥5 daughters (n=980)</td>
<td>0.41</td>
<td>0.45</td>
</tr>
<tr>
<td>Sires with ≥10 daughters (n=733)</td>
<td>0.43</td>
<td>0.49</td>
</tr>
<tr>
<td><strong>Removal Parity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Sires (n=3,875)</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Sires with ≥5 daughters (n=893)</td>
<td>0.34</td>
<td>0.22</td>
</tr>
<tr>
<td>Sires with ≥10 daughters (n=669)</td>
<td>0.34</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Lifetime Born Alive</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Sires (n=3,875)</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Sires with ≥5 daughters (n=893)</td>
<td>0.29</td>
<td>0.23</td>
</tr>
<tr>
<td>Sires with ≥10 daughters (n=669)</td>
<td>0.30</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*a* A total of 251,992 service records were collected on 47,898 sows. Service records were collected from 1996 to 2008. Litters per sow per year breeding values were estimated from records on 68,662. Records were collected from October 1993 to June 2009. Litters per sow per year breeding values were estimated using a model as described in the text. All correlations are significantly different from zero (P<0.01).
Figure 4.1
Average sire progeny means for farrowing rate, removal parity, and lifetime born alive for each 5% percentile of litters per sow per year (LSY) estimated breeding value (EBV) using all sires from a Thai swine production system\textsuperscript{a}

\textsuperscript{a}A total of 251,992 service records were collected on 47,898 sows. Service records were collected from 1996 to 2008. Litter records were collected from October 1993 to June 2009. Litters per sow per year breeding values were estimated using a model as described in the text.
Figure 4.2
Average sire progeny means for farrowing rate, removal parity, and lifetime born alive for each 5% percentile of litters per sow per year (LSY) estimated breeding value (EBV) using sires with 10 or more daughters from a Thai swine production system.

A total of 251,992 service records were collected on 47,898 sows. Service records were collected from 1996 to 2008. Litters per sow per year breeding values were estimated from records on 68,662. Litter records were collected from October 1993 to June 2009. Litters per sow per year breeding values were estimated using a model as described in the text.
CHAPTER 5: GENERAL CONCLUSION

The goal of this project was to examine the value of incorporating litters per sow per year (LSY) into a swine selection program for improving maternal line productivity. The trait was chosen because of its relationship with production efficiency of commercial pork production. The average LSY in the U. S. is 2.27 (PigCHAMP, 2010). The trait is a measure of how quickly a sow can produce a litter. The components of LSY include: 1) entry to first service, 2) gestation length, 3) weaning to first service interval, 4) farrowing rate, 5) farrowing interval, and 6) culling to removal interval.

Entry to first service interval is the time from a female’s entry into the breeding herd to the time she is first mated. Entry to first service interval is herd dependent and based on the swine operation’s management system. Since it is a management trait, traditional selection is not useful in improving or reducing the number of entry to first service days. Gestation length is heritable; however, there is little biological variation which prevents efficient improvement through selection. Even if efficient selection was possible, there is an optimal gestation length for the best piglet performance. If the gestation length is increased too much, then piglet birth weight will be too large, and sows could have trouble farrowing. This may result in an increased number of caesarian sections, increased instances of dystocia, and/or increased sow mortality. If the gestation length is too short, the piglets are not fully developed, and may not be viable when born. Improvement in the interval from weaning to service is limited biologically. Sows have to have time to come into estrus before they can be bred. It is important for producers to have well-developed management practices in order to ensure proper heat detection so that every sow in estrus is mated. Farrowing rate is affected by management and genetics. There is room to make genetic improvement for farrowing rate.
Improving farrowing rate can in turn improve the farrowing interval by reducing the number of non-productive days accumulated by sows being open.

The cost of a non-productive day is between $1.60 and $2.60 per sow (Rix and Ketchem, 2009). The average number of non-productive days in a herd is approximately 35 days per year. This is a cost of between $56 and $91 per sow per year. Assuming a cost a $2.00 per non-productive day per sow, a breeding herd with 2,400 sows can save $24,000 a year by reducing their average non-productive days by 5. Reducing the number of non-productive days in the breeding herd will improve the profitability of the swine operation by reducing the cost of producing a market hog. Increasing LSY and reducing non-productive days will improve the throughput per unit of cost meaning that more piglets will be produced for the same sow cost. This could result in improved profitability for the producer by increased production and economic efficiency for individual sows and the operation in its entirety (Stalder, 2000).

The average number born alive per litter in the U. S. is 11.6 (PigCHAMP, 2010). As the number born alive is approaching the optimum in the U. S., a novel trait must be used to improve the sow herds. When the number of piglets produced in a litter is at a desirable level, the next step to improve sow efficiency would be to decrease the time it takes for a sow to produce a litter. This would reduce the costs associated with the development of each market hog, since sows will consume less maintenance feed due to the fewer days taken to produce a single litter.

The decision to use LSY in a maternal line selection program is dependent on several factors. The trait must be heritable. If there is no genetic component, improvement can only be attained by improving the environmental component of the trait. In this project, the
heritability of LSY was estimated for two different systems. The estimate obtained from the commercial breeding company was 0.03, while the estimate obtained from the integrated production system was 0.11. These estimates suggest that there is a genetic component of LSY and the trait can be improved through traditional selection methods. Since heritability estimates will vary for each production system, LSY may be heritable in some production systems and not heritable in others in order to avoid negatively impacting traits where an undesirable relationship exists with LSY.

The genetic correlations between LSY and other economically important trait must be considered before the trait is included as part of a selection program. If desirable correlations exist, then selection for LSY can indirectly improve other traits. If undesirable correlations exist and the producer still wants to select for LSY, these must be accounted for in the selection index.

In this project, the genetic correlations between LSY and three post-weaning growth traits (days to 100 kg, percent lean, and backfat) and two reproductive traits (number born alive and wean to estrus) were estimated. The estimates of the genetic correlations between LSY and days to 100 kg, percent lean, and backfat were $0.26 \pm 0.19$, $-0.16 \pm 0.14$, and $0.02 \pm 0.14$, respectively. Due to the large standards errors, these correlations are not significantly different from zero. No correlation between LSY and the post-weaning growth traits would suggest that there is not an antagonistic relationship among the traits. The genetic correlations between LSY and number born alive and wean to estrus were estimated to be $-0.21 \pm 0.28$ and $-0.96 \pm 0.04$, respectively. The genetic correlation between LSY and number born alive is not significantly different from zero. This suggests that selection for LSY would not adversely affect number born alive. The genetic correlation between LSY
and wean to estrus is large and favorable. This suggests that increasing LSY would indirectly reduce the wean to estrus interval.

This project also examined the relationship between sire breeding values for LSY and sire progeny (daughter) means for farrowing rate, removal parity, and lifetime born alive. The LSY breeding value was favorably correlated with all three traits. The averages for farrowing rate, removal parity, and lifetime born alive in the U. S. are 84%, 4.5, and 46.4 pigs, respectively (PigCHAMP, 2010 and Stalder et al. 2009). This provides evidence that selecting sires with high LSY breeding values to improve the LSY could also improve the herd farrowing rate, removal parity, and lifetime born alive. Sires ranked in the top 25% for LSY breeding values had a 15.3% higher average progeny means for farrowing rate compared to sires in the bottom 25%. The top sires had one parity higher average daughter removal parity than the bottom sires. This extra litter corresponded to an average of 8.9 more pigs produced in a sow’s lifetime. At $22 per piglet born alive, this is almost $198 increased revenue per sow (NSR, 2009).

This project has shown that there is potential for incorporating LSY into a selection program with the goal to improve overall herd production efficiency. There is not a significant antagonistic correlation between LSY and the post-weaning growth traits considered in this study. This indicates that selecting for LSY should not have an undesirable effect on days to 100 kg, percent lean, and backfat. There is a favorable correlation between LSY and wean to estrus. There is a favorable relationship between sire LSY breeding values and daughter phenotypes for farrowing rate, removal parity, and lifetime born alive. Improving these three traits can increase the profitability of swine operations. An improved farrowing rate means fewer non-productive days or days open in the sow herd. Each non-
productive day costs the producer approximately $2.00 per sow. An increased removal parity means higher longevity for the sows. Improving the sow’s longevity means she is given more opportunity to produce enough piglets to sufficiently pay for herself and begin making a profit for the producer (Stalder, 2002). As long as sows are producing litters with numbers and weights at herd average, they should not be removed from the herd and replaced with gilts. The improved genetics of the gilts will not offset their initial replacement and gilt development costs (Abell et al., 2010). Increasing the number of piglets produced in a sow’s lifetime increases the amount of saleable product for the operation. This, in turn increases overall revenue.

Further research must be conducted to estimate the heritability of LSY in other swine operations. The relationships between LSY and other economically important traits should also be estimated in other populations. If similar values are found across populations, the evidence for the inclusion of LSY in a maternal line selection program would be strengthened. It is important that the heritability and relationships be estimated on a population basis before the trait is incorporated into a sow selection program.
CHAPTER 6: LITERATURE CITED


APPENDIX: TRAIT DISTRIBUTIONS

Figure A.1. Distribution of number born alive from an Irish commercial breeding company\textsuperscript{a}

\textsuperscript{a}The dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. Number born alive was collected on every litter.
Figure A.2. Distribution of litters per sow per year from an Irish commercial breeding company\textsuperscript{a}

\textsuperscript{a}The dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. Litters per sow per year was calculated as described in the text.
**Figure A.3.** Distribution of weaning to estrus interval from an Irish commercial breeding company

The dataset contained 32,602 litter records of Landrace, and Yorkshire sows from November 1992 to December 2010. A total of 7,674 sows from 4 herds were used in the analysis. Weaning to estrus interval was recorded for every litter.
Figure A.4. Distribution of backfat (mm) adjusted to 100 kg from an Irish commercial breeding company

There were 44,040 growth records in that data set collected on Landrace and Large White pigs from 1999 to 2010. Backfat was recorded post-weaning.

There were 44,040 growth records in that data set collected on Landrace and Large White pigs from 1999 to 2010. Backfat was recorded post-weaning.
**Figure A.5.** Distribution of days to 100 kg from an Irish commercial breeding company

There were 44,040 growth records in that data set collected on Landrace and Large White pigs from 1999 to 2010. Days to 100 kg was recorded post-weaning.
Figure A.6. Distribution of percent lean from an Irish commercial breeding company. 

There were 44,040 growth records in that data set collected on Landrace and Large White pigs form 1999 to 2010. Percent lean was recorded post-weaning.
Figure A.7. Distribution of number born alive from a Thai production system

The dataset contained 231,858 litter records of Landrace, Large White, and F1 cross sows from October 1993 to June 2009. A total of 48,662 sows from 9 herds in a single production system were used in the analysis. Number born alive was collected on every litter.
Figure A.8. Distribution of lifetime born alive from a Thai production system

The dataset contained 231,858 litter records of Landrace, Large White, and F1 cross sows from October 1993 to June 2009. A total of 48,662 sows from 9 herds in a single production system were used in the analysis. Lifetime born alive was calculated as the sum of each number born alive record for the sow.
Figure A.9. Distribution of litters per sow per year from a Thai production system\textsuperscript{a}

\textsuperscript{a}The dataset contained 231,858 litter records of Landrace, Large White, and F1 cross sows from October 1993 to June 2009. A total of 48,662 sows from 9 herds in a single production system were used in the analysis. Litters per sow per year records were extracted from PigCHAMP\textsuperscript{TM}.
Figure A.10. Distribution of farrowing rate from a Thai production system
a
A total of 251,992 service records were collected on 47,898 Large White, Landrace, and F1 cross sows. Service records were collected from 1998 to 2008 from 9 herds in a single production system. Farrowing rate was calculated as the number of farrowings for the sow divided by the number of services for the sow.
Figure A.11. Distribution of removal parity from a Thai production system

The dataset contained 231,858 litter records of Landrace, Large White, and F1 cross sows from October 1993 to June 2009. A total of 48,662 sows from 9 herds in a single production system were used in the analysis.