Duroc boars have lower progeny mortality and lower fertility than Pietrain boars[1]

Marie Louise M. Pedersen,[†,2] Ingela H. Velander,[†] Mai Britt F. Nielsen,[†] Nils Lundeheim,[‡] and Bjarne Nielsen[†]

[†]SEGES, Pig Research Centre, Danish Agriculture and Food Council, Copenhagen V DK-1609, Denmark; and [‡]Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, Uppsala SE-750 07, Sweden

ABSTRACT: In pig production, Pietrain and Duroc lines are often used as terminal sire lines to produce crossbred slaughter pigs. The objective of this study was to identify the differences in paternal fertility and mortality during the suckling period of crossbred progeny from Pietrain and Duroc terminal sire lines. In total, 87 purebred Duroc boars and 68 purebred Pietrain boars were used as terminal sires to produce 1,823 crossbred Duroc litters (D-litters) and 1,705 crossbred Pietrain litters (P-litters) in two production herds. The sows were crosses between DanBred Landrace and Yorkshire (F1). All boars were kept at the same artificial insemination (AI) station, and all semen doses were produced in the same laboratory. The experiment was balanced according to herd, boars, and time, with approximately 13 sows from each herd mated to each boar within each breed. The results showed higher fertility expressed as litter size at birth in P-litters compared with D-litters led to 0.5 higher total number born (TNB) for P-litters ($P = 0.0076$). However, piglet mortality including number of stillborn piglets was lower in D-litters compared with P-litters ($P < 0.0001$), and 5 d after farrowing, the average litter size in P-litters ranged 0.4 below the litter size in D-litters ($P < 0.027$). At 21 d after birth, mean litter size in P- and D-litters were 14.5 and 14.9 piglets per litter, respectively ($P < 0.015$). This indicated that Pietrain progenies were weaker than Duroc progenies, and it was concluded that use of Duroc boars as the terminal sire line led to lower piglet mortality. In the two herds, the mean piglet mortality rate including still born piglets ranged from 19.5% to 23.6% and from 17.6% to 19.1% in P- and D-litters, respectively.

Key words: Duroc, fertility, mortality, Pietrain, terminal sire, total number born

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INTRODUCTION

In commercial pig production, the number of weaned pigs is a key factor to increase productivity and, therefore, selection for increased litter size has been a part of the breeding program in many female lines of different breeding companies. Selection strategy on the maternal genetic effect of litter size has resulted in a considerable increase in litter size (Sorensen et al., 2000; Su et al., 2007; Nielsen et al., 2013). The maternal genetic effect of fertility, litter size, and piglet survival has been considered in a number of quantitative genetic studies (Sorensen et al., 2000; Grandinson et al., 2002; Knol et al.,

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[2]Corresponding author: mlp@seges.dk

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2002; Su et al., 2007, 2008). Selection for the paternal effect on litter size has got less attention even though it has been shown to affect the number of piglets per litter significantly at birth and weaning (Rahnefeld and Swierstra, 1970). The heritability estimates from terminal sires were found to be 3-fold lower than for dam (van der Lende et al., 1999). Nevertheless production results showed that the differences in litter size vary by two piglets for the 10% top boars to the 10% bottom boars (Roca et al., 2015) and individual boars and genetic line of boars affects farrowing rate and total number of born piglets (Sonderman and Luebbe, 2008; Broekhuijse et al., 2012). It has been reported that the terminal sire influence on the genetic variances of litter size ranged from 2% to 5% (Hamann et al., 2004; Wolf and Wolfova, 2012). However, the effect on litter size and mortality during suckling period affected by the terminal sire lines used are unknown and have never been identified experimentally in production. Especially for use of Duroc or Pietrain, which are frequently used as terminal sires lines in commercial production of crossbred piglets, it is important to obtain a high number of weaned piglets and a low mortality rate. The object of the study was to identify the differences in paternal fertility and mortality during the suckling period of crossbred progeny from Pietrain and Duroc boar lines used as terminal sires.

MATERIAL AND METHODS

Experimental Design

Sires from 87 purebred Duroc and 68 purebred Pietrain were used as terminal sires to produce 1,823 Duroc crossbred litters (D-litters) and 1,705 Pietrain crossbreed litters (P-litters) in two production herds denoted M and A. The litters were produced by 966 and 1,194 sows in two herds M and A, respectively. Numbers of litters, sows, boars, and the different traits of litter size in each herd are shown in Table 1. Some boars (13 Duroc and 8 Pietrain) were only used in one herd. The Duroc boars came from the DanBred Duroc population and were available for commercial production. The Pietrain boars were imported from Germany to Denmark and were all purebred boars from the German Piétrain line, available for the market for commercial production. To increase the genetic variances, boars that were full sib brothers were avoided. The Pietrain and Duroc boars were hosted at the Danish artificial insemination (AI) station Hatting-Viborg in two different sections and semen doses were produced according to Danish commercial standard of single sire doses (the semen doses contained a minimum of 1.5 billion motile sperm cells and was diluted in an ethylene-diamine-tetra-acetate extender). All used semen doses were produced and distributed from the same laboratory.

Table 1. Descriptive statistics by herd and breed: Number of mated sows, number of litters for TNB, LS5 and LS21 after birth, number of terminal Duroc and Pietrain boars

	Herd M		Herd A	
	Pietrain	Duroc	Pietrain	Duroc
Mated sows	854	843	999	1,135
Litters for TNB	765	744	940	1,079
Litters for LS5	748	718	936	1,068
Litters for LS21	748	718	936	1,068
Boars for TNB	56	67	68	87

All sows were crossbreds between DanBred Landrace and DanBred Yorkshire (F1). Due to practical reasons first parity litters were not included in the study, and thereby the parities of the sows ranged from 2 to 7.

The experiment setup was a sire experiment designed to be balanced according to herd, boars, and farrowing group. Thereby, most of the sires were used in both herds (Table 1). Within a week after weaning of previous litters, the sows were randomly selected for boar breed and single sire mated with either Pietrain or Duroc boar. In herd A, a farrowing group of about 27 sows were inseminated each week with semen from about two boars from each sire line, and in herd M, a farrowing group of 54 sows were inseminated each second week with semen from about three boars from each sire line. The experimental inseminations were performed from 8 January 2014 to 9 September 2015. Every boar delivered semen doses over a period of about 5 wk and the Pietrain and Duroc boars had an equal production time. Several of the sows were included in the experiment with more than one litter in the experimental period. The proportion of sows that delivered 1, 2, 3, and 4 litters were 53%, 24%, 15%, and 8%, respectively.

During gestation, dead sows, repeated breeders, and sows having abortions were recorded. Farrowing rates were obtained as the ratio of farrowing sows in relation to mated sows.

At farrowing and within the first 12 h, the total number born (TNB) and number of still born piglets, including dead piglets in premature lifetime, were recorded. Within 1 d after birth and after colostrum intake, all piglets were earmarked using an individual identification number. In total, 57,977 piglets were earmarked. To avoid loss of identification, each pig was earmarked in both ears with two copies of same identification number. After individual identification of the piglets, the litter size were equalized and each sow was assigned 13 or 14 piglets to nurse. The number of piglets assigned to each sow depended on management in the two herds. Equalizing the number of piglets per sow was done by moving piglets between litters (if needed), and it was allowed to do so during the whole suckling period. Furthermore, to avoid weak piglets, weight loss, or death of piglets, all commercial management tools were allowed, e.g., use of cross fostering. The movements of piglets to foster mother were not recorded and cross-fostering between offspring of the two sire lines might occur. All recordings of litter size at day 5 and at day 21 were recorded for the biological mother of each piglets and no information was recorded on the nurse sow (foster mother).

During the suckling period, up to day 21 after farrowing, all dead piglets were recorded and assigned (according to the earmarks of piglets) to the biological mother and thereby also to the terminal sire of the piglets. For all dead piglets, the age of dead piglets was recorded. Litter size at 5 d after farrowing (LS5) of each biological mother was calculated as the TNB minus the number of stillborn and dead piglets up to day 5 after farrowing. Similar, the litter size at 21 d after farrowing (LS21) of each biological mother was calculated as the TNB minus the number of stillborn and dead piglets up to day 21 after farrowing. The mortality rate up to day 5 (MORT5) after farrowing was calculated as (TNB − LS5)/TNB in each litter and the mortality rate during suckling period up to day 21 (MORT21) was calculated as (TNB – LS21)/TNB in each litter. The difference in number of litter recordings of TNB and LS5 in Table 1 reflect either missing observations for TNB or differences in recorded number of piglet born alive and the number of earmarks assigned to each biological mother.

Statistical Analysis

Litter size and mortality recorded up to day 21 after farrowing were analyzed using a univariate linear mixed model, i.e.,

$$y_{pbhig} = \mu + \text{par}_p + \text{breed}_b + \text{herd}_h + (\text{breed} \times \text{herd})_{bh} + s_i + g_g + e_{pbhig}$$

in which y_{pbhig} denotes the values of either TNB, LS5, LS21, MORT5, or MORT21 recorded for each litter; μ denotes the overall mean of the trait, par_p is the fixed effect of parity p, breed_b is the fixed effect of sire line b (Duroc or Pietrain), herd_h is the fixed herd effect, $(\text{breed} \times \text{herd})_{bh}$ is the herd and breed interaction effect, $s_i \sim N(0, \sigma_s^2)$ is the random effect of sire i, $g_g \sim N(0, \sigma_g^2)$ is the random group effect of farrowing group g, and $e_{pbhig} \sim N(0, \sigma_e^2)$ is the random residual effect. The sire effect s_i was nested within the breed effect breed_b, and the group effect g_g was nested within herd effect herd_h. This implies that significance of breed effect and interaction between breed and herd effect were tested against the sire effect. All random effects were assumed to be independent and independent of fixed effect levels.

The model above was also extended to include two different variances, $\sigma_{s,b}^2$ related to each of the two sire lines, i.e., $s_i \sim N(0, \sigma_{s,b}^2)$.

Farrowing rate was analyzed as a binary trait using generalized linear mixed model of the form:

$$E(y_{pbhig}) = \mu + \text{par}_p + \text{breed}_b + \text{herd}_h + (\text{breed} \times \text{herd})_{bh} + s_i + g_g$$

in which for each litter, *pbhig*, an underlying liability of farrowing was assumed. A *probit* link function $f(y_{pbhig}) = \Phi^{-1}y(y_{pbhig})$ was introduced and y_{pbhig} is the probability of success, and Φ is the cumulative Gaussian distribution. Success was obtained for sows that farrowed and failure was obtained for inseminated sows that failed to farrow. In the model above, μ is the overall mean, par_p is the effect of parity p, breed_b is the effect of sire line b (Duroc or Pietrain), herd_h is the herd effect, s_i is the sire effect, g_g is the effect of farrowing group g. Significance of the breed effect and interaction between breed and herd effect were tested against the sire effect.

For all dead piglets, the age of dead was analyzed using a univariate linear mixed model, i.e.,

$$y_{pbhijgk} = \mu + \text{par}_p + \text{breed}_b + \text{herd}_h + (\text{breed} \times \text{herd})_{bh} + s_i + d_j + g_g + e_{pbhijgk}$$

in which $y_{pbhijgk}$ was the age of dead of piglet k in the litter within the sire i and the dam j. The other effects are designated as in the models above.

All models were applied to data by using PROC MIXED or PROC GLIMMIX in SAS Enterprise Guide 7.1.

RESULTS

Across the two herds, the two terminal sire lines obtained the same mean farrowing rate of 92% whether the sows were inseminated with Duroc semen or Pietrain semen (Table 2). When Pietrain boars were used as the terminal sire line, the TNB per litter was significantly higher (18.7) than when Duroc boars (18.2) were used (P = 0.0076; Table

Table 2. Least square means by breed (including df for denominator in the *F*-test of significance), significance levels (*P*-values) of main effects and interaction between boar line and herds, and significance of parity effects for the different traits: farrowing rate, TNB, LS5 and LS21 after birth, MORT5, MORT21, and age of death

		LS-means			Breed	Herd	Breed × herd	Parity
	Herd	Pietrain	Duroc	df	*P*-value	*P*-value	*P*-value	*P*-value
Farrowing rate, %	–	92	92	160	ns	<0.0001	ns	ns
TNB, *n*	–	18.7	18.2	127	0.0076	<0.0001	ns	<0.0001
LS5, *n*	–	14.8	15.2	118	0.027	<0.0001	ns	<0.0001
LS21, *n*	–	14.5	14.9	118	0.015	<0.0001	ns	<0.0001
MORT5, %	M	17.5	16.0	129	<0.0001	0.0002	0.0004	<0.0001
	A	21.5	16.8					
MORT21, %	M	19.5	17.6	131	<0.0001	<0.0001	0.0048	<0.0001
	A	23.6	19.1					
Age at death, days	M	4.6	4.2	157	ns	<0.0001	<0.0001	<0.0001
	A	3.2	3.9					

Nonsignificance is indicated by "ns".

2). The Pietrain boars produced 0.5 more TNB than Duroc boars. However, the higher TNB of the Pietrain sires (18.7) did not result in higher number of piglets at day 5 after farrowing (14.8) compared with Duroc (18.2 and 15.2). The litter size at day 5 was slightly significant higher in Duroc ($P = 0.027$), and at day 21, the litter size of Pietrain progeny litters (14.5) was significant less than litter size in Duroc progeny litters (14.9, $P = 0.015$).

Regardless of the sire line used, the significance of the herd effects for the traits of TNB, LS5, and LS21 shows different production levels in herds A and M (Table 2, $P < 0.0001$ in all three traits).

The traits of MORT5 and MORT21 show that significantly more piglets of Pietrain progeny died ($P < 0.0001$) and the interaction between breed and herd was significant on day 5 after farrowing ($P = 0.0004$). The interaction between breed and herd was also significant for MORT21 showing different mortality rates in the two herds M and A ($P = 0.0048$; Table 2). In herd A, the mortality in P-litters took place earlier than in D-litters: the mean ages of death were 3.2 and 3.9, respectively. In herd M, the opposite pattern was observed, and the mean ages of death were 4.6 and 4.2 for P-litters and D-litters, respectively (Table 2). The reduction in litter size during the suckling period shows that during the first day after farrowing, the mortality of Pietrain piglets were higher than for Duroc piglets (Figure 1). The following suckling days up to 20 d after farrowing, the difference in mortality between Pietrain and Duroc progeny vanished.

The lower mortality in D-litters reflected by higher survival rate was linear for all levels of TNB and ranged from 12 to 26 TNB (Figure 2). The survival rate in D-litters was about 3% higher than in P-litters (Figure 2). As indicated in Figure 2, survival in P-litters for the small litters with 14 TNB was about 85%, while survival in Duroc was about 88%. In large litters with 24 TNB, the survival in Pietrain and Duroc was 73% and 76%, respectively (Figure 2). Although the Pietrain sires produced a higher number of piglets at birth and the survival rate thereby might be lower, Figure 2 however shows lower survival rate of Pietrain progeny than for Duroc progeny, independent of TNB.

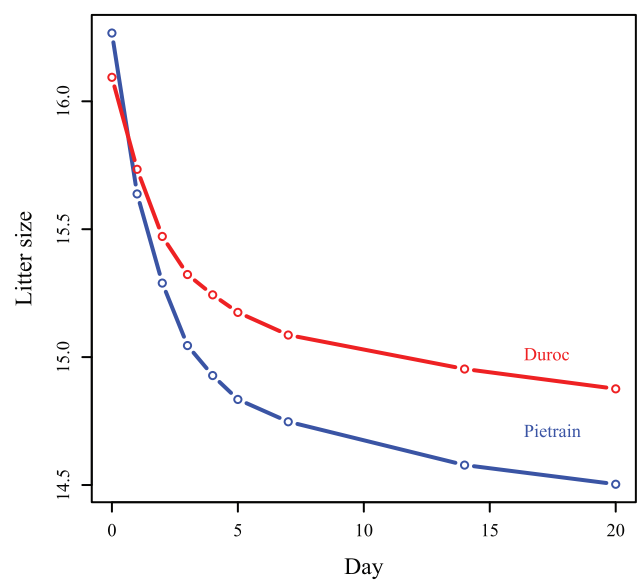

Figure 1. Mean litter size during the first 20 d after birth of litters from Duroc and Pietrain.

At sire level, there was no clear relation between predicted boar levels of TNB and MORT21 (Figure 3). It shows that the higher mortality rate in the Pietrain progeny was independent of TNB.

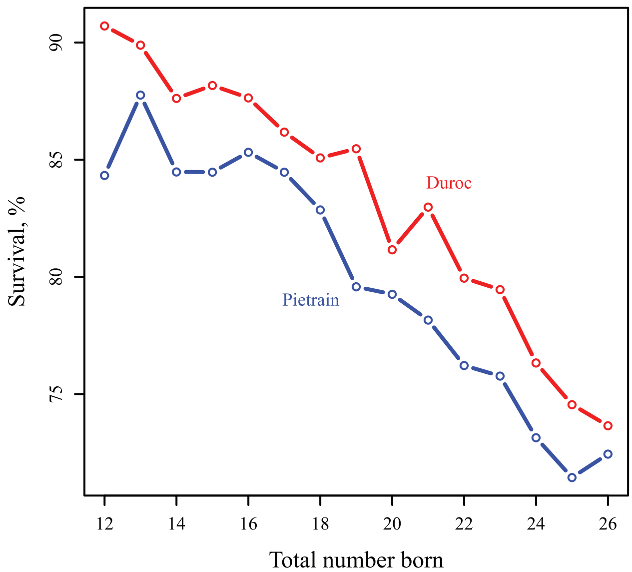

Figure 2. Mean survival rate in relation to TNB in litters of Duroc and Pietrain boars.

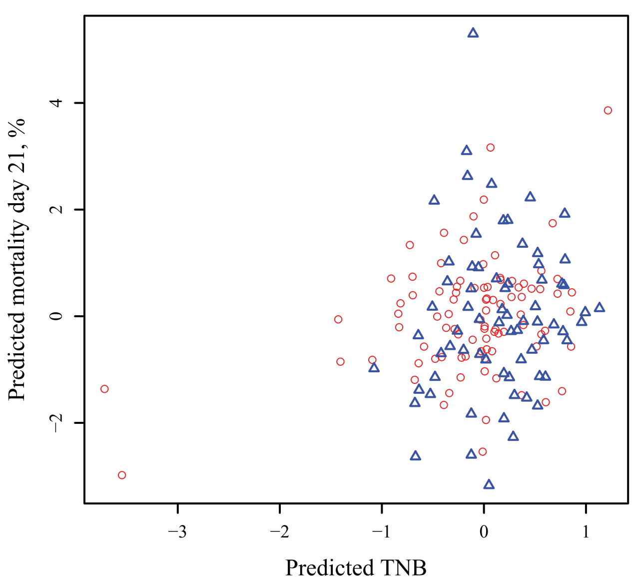

Figure 3. Best linear unbias prediction (BLUP) of the random sire effect *si* for each boar related to mortality 21 d after farrowing (MORT21) and TNB per litter: Pietrain (blue triangles) and Duroc (red circles).

However, Figure 3 also indicates three extreme (outlier) boars. Two Duroc boars showed low levels of predicted TNB and one Pietrain boar showed a high predicted level of MORT21. The extreme boars increase the variances especially for TNB.

The highest variance in litter size was obtained at birth for TNB obtaining 12.50 (Table 3). After birth, the variances were decreased to 10.18 for LS5 and 10.13 for LS21. The decrease in variances might relate to the decrease in mean litter size during the suckling period (Table 2). The highest variance due to sire effect was obtained also at birth for the TNB at 0.66 covered 5.3% of the total variance. After birth and during the suckling period, the sire effect decreased more than the total variances, and at day 21, the sire variation accounted for 3.8% of the total variation in litter size (LS21; Table 3). During the same period, the variance of environmental farrowing group effect increased from 0.2% to 1.4%. However, the variance affected by the farrowing group was still of minor level compared with the residual variance that cover most of the environmental variance in litter size.

Using the model which allows for individual variances within Pietrain boars and within Duroc boars (i.e., sire variance$s_i \sim N(0, \sigma^2_{s,b})$), the variance of TNB between boars were found to be higher for Duroc (1.11) and lower for Pietrain (0.10) (Table 3). The higher variation in TNB between Duroc boars compared with the variance between Pietrain boars was clearly shown in the probability plot of the boars (Figure 4). In the probability plot, the boars are ranked from the lowest to the highest predicted level of TNB, and if the predicted boar levels follow a trend line, then they will be Gaussian distributed, which was assumed in the models. Boars which deviate from the trend line deviate from the expected Gaussian distribution and increase the sire variance. Variations between Pietrain boars have a minor effect on TNB; however, for Duroc, a much larger variation between boars in TNB was found. The two lowest ranked Duroc boars obtain a litter size about two piglets below the expected mean level for TNB and the two second lowest Duroc boars ranked 0.5 piglets below the expected mean level for TNB (Figure 4). Except from extreme Duroc boars, the probability plot runs two parallel trend lines indicating Gaussian distribution of both boar lines. The two lowest ranked Duroc boars were already shown to have low litter size in Figure 3. After birth, the difference in variances between Pietrain and Duroc sire lines decreased to 0.30 and 0.23 for LS5 and 0.30 and 0.19 for LS21, respectively (Table 3).

DISCUSSION

This study shows the differences in levels of TNB and LS21 when using the two terminal sire lines in a cross breeding program in two commercial production herds. In both herds, a higher mortality rate was found for Pietrain progeny compared with Duroc progeny. The highest mortality rate was found in herd A and here the mortality rate decreased 4.5 units of percentage from 23.6% to 19.1% by use of Duroc compared with use of Pietrain as the terminal sire line (Table 2). In the other herd with a lower mortality, the mortality rate only decreased 1.9 units of percentage from 19.5% to 17.6%. The different effect on

Table 3. Total variance and ratios of variances associated to the random effect of sire, farrowing group, and residual in three estimated models for trait of: TNB, LS5, and LS21

	TNB		LS5		LS21	
Sire	0.66	5.3%	0.41	4.0%	0.39	3.8%
{Pietrain}	{0.10}	–	{0.30}	–	{0.30}	–
{Duroc}	{1.11}	–	{0.23}	–	{0.19}	–
Farrowing group	0.03	0.2%	0.10	1.0%	0.14	1.4%
Residual, %	11.81	94.5%	9.67	95.0%	9.60	94.8%
Total	12.50	100.0%	10.18	100.0%	10.13	100.0%

Variances from models that allow for estimates of different variances within Pietrain sires and Duroc sires are shown in brackets {}.

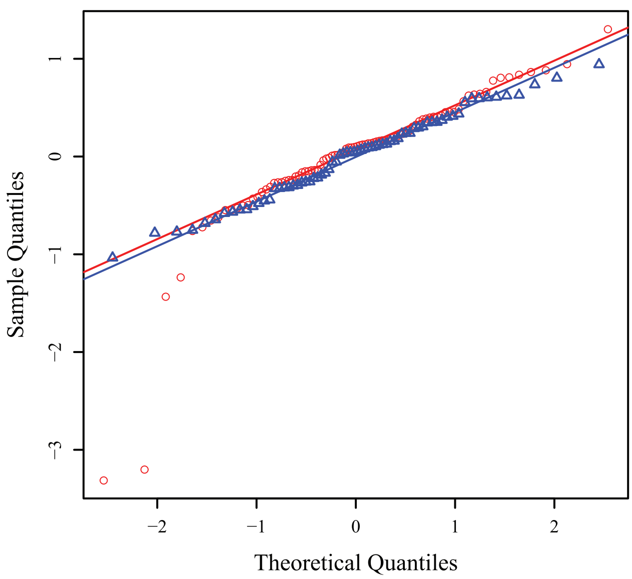

Figure 4. Probability plot of BLUP of the random sire effect *si* for each boar related to TNB per litter, by sire line: Pietrain (blue triangles) and Duroc (red circles). The predicted means (BLUP) were obtained from the linear mixed model of TNB.

mortality rate from the two sire lines in the two herds demonstrated the significant interaction between sire lines and herd. The mortalities until day 5 and until day 21 were significant higher in herd A compared with herd M ($P = 0.0004$ and $P = 0.0048$; Table 2). Thereby, the study clearly demonstrates how the choice of sire line have a practical impact on piglet mortality, and especially in a herd with high mortality, the differences between P-litters and D-litters were highest and in favor by use of the Duroc sire line.

The results in this study depend, to a certain extent, on the choice of sires within each sire line. The Duroc line was the DanBred Duroc line, available for commercial herds in Denmark. The Pietrain line was the German Piétrain and this line is among the most used in Germany. The Pietrain boars were transported to Denmark and placed in a Danish AI station where semen was collected and treated according to normal standards in Denmark. The main aim was to use boars reflecting the population average and most importantly to use boars that were unrelated to each other to get as much genetic variation as possible. However, it was not possible to find completely unrelated Pietrain boars when importing 68 different boars. This was easier in the selection of Duroc boars as these were selected arbitrary among the 260 boars at the AI station.

The farrowing rates in our study were about 92% and no difference in farrowing rates for the two sire lines were observed (Table 2). High farrowing rate was expected as no first parity sows were included in the experiment. Low farrowing rates has been observed in first parity sows (Koketsu et al., 1999). Farrowing rate is mostly associated to the sow lines and different lines have different level of farrowing rate; however, also the choice of sire within breed affects the farrowing rate (Sonderman and Luebbe, 2008; Broekhuijse et al., 2012; Roca et al., 2015). Sonderman and Luebbe (2008) reported that farrowing rates ranged from 71.8% to 92.2%, having the lowest rates for Landrace, Yorkshire, and Duroc and the highest rate for Meishan boars. Broekhuijse et al. (2012) found a variation in farrowing rate of 5.3%, which could be explained by the boar. Farrowing rate is also strongly affected by management (Koketsu et al., 1997; King et al., 1998), and the herds in this study were commercial pig producers having a high production level.

The proportion of service sire variances of TNB, LS5, and LS21 ranged between 0.038 and 0.053 with the highest variation at birth for TNB and the lowest variation at week 3 for LS21 (Table 3). Previous studies showed that the proportion of genetic sire variation ranged from 0 to 0.05 (van der Lende et al., 1999; Hamann et al., 2004; Wolf and Wolfova, 2012). However, the sire variances in this study were on a high level (0.053 on TNB) and it might be due to high fertility of the sows and the high number of TNB. Wolf and Wolfova (2012) showed service sire variance on 0.03 for TNB at about 12 piglets per litter. In our study, mean litter size ranged between 18.2 and 18.7 in D-litters and P-litters. All sows were crossbred sows of DanBred Landrace and Yorkshire and they all had high female fertility and large phenotypic litter size, which increased the experimental variance of litter size, and thereby increased the sire fertility variance to be significant, and it also obtained a higher ratio compared with other studies. This study showed that Pietrain boars used as terminal sire resulted in higher TNB than for Duroc boars, and thereby the Pietrain boars are shown to be more fertile than Duroc boars. It indicates that Pietrain semen had higher fertilization ability than semen of Duroc boars. Previous studies have shown that boars of unknown breeds perform different with respect to TNB (Broekhuijse et al., 2012; Roca et al., 2015). One study found that 5.9% of the variation in TNB was boar or semen related (Broekhuijse et al., 2012). Roca et al. (2015) reported a variance of TNB ranging from 1.51 to 1.86 in boars from commercial AI station. The variation of TNB within D-litters was higher than for P-litters and the larger variation for Duroc was mostly affected by two Duroc sires (Figure 4). Two of those sires obtained mean levels lower than two piglets per litter below the expected mean of TNB (Figure 4). Numerous studies have investigated the causes of low fertility on an individual level and semen quality in Duroc (Xu et al., 1998; Popwell and Flowers, 2004) and found that genetic defects like reciprocal chromosomal translocation (Kuokkanen and Mäkinen, 2008; Rodríguez et al., 2010; Quach et al., 2016) could be one reason for low litter size. Fertility problems caused by low semen quality can be minimized by finding the boars with defects of the semen by objective semen analyses like computer-assisted motility analysis (CASA). The CASA measurements correlate with field fertility results (Holt et al., 1997; Broekhuijse et al., 2012). However, boars with genetic defects like reciprocal chromosome translocation show no phenotypic signs (Kuokkanen and Mäkinen, 2008). Thereby, the TNB in litter size for each boar is the only reliable response of the male fertility. In this study, it was not possible to investigate why some Duroc boars had lower fertility.

This study showed that Pietrain boars used as terminal lines resulted in higher TNB than use of Duroc boars. However, the LS5 and LS21 for D-litters were higher than for P-litters. Furthermore, in herd A, the Pietrain progeny died at a younger age than the Duroc progeny. The mean age of death of Pietrain and Duroc were 3.2 and 3.9 d, respectively, indicating that the Pietrain progenies were weaker at birth than Duroc progenies (Table 2). In herd M, the opposite pattern was observed, and the mean age of death were 4.6 and 4.2 d for Pietrain and Duroc progeny, respectively. The study shows that already at birth and in the first primal lifetime of piglets, the Duroc progenies were more robust with better vitality than Pietrain sire progenies (Figure 1). A large number of studies have shown that the sires affect the litter size (Chen et al., 2003; Hamann et al., 2004; Wolf and Wolfova, 2012). However, a comparison between different breeds of terminal sire lines has never been studied for piglet mortality or piglet survival. It was surprising that the significant difference in TNB ($P = 0.0076$) of 0.5 piglets at farrowing in benefit for Pietrain boars were equalized during the suckling period and ended up with slightly significant ($P = 0.015$) 0.4 more piglets per litter at day 21 produced by Duroc boars (Table 2). It shows that the mortality rate was larger in P-litters than in D-litters in the same time frame. The total mortality rate obtained as means of the mortality rates in all litters during the suckling period, including still born piglets, range from 19.1% to 23.6% in herd A and from 17.6% to 19.5% in herd M in Duroc and Pietrain progeny, respectively (Table 2). One reason could be that high TNB levels lead to lower average birth weight and thereby the causes of mortality increases due to weakness at birth, starvation, or crushing (Strange et al., 2013). The unfavorable relation between TNB and mortality has been shown in many studies (Högberg and Rydhmer, 2000; Damgaard et al., 2003). It is however important to mention that in these studies, only maternal effect of TNB was considered.

The higher piglet survival for progenies of Duroc was well demonstrated by all litter size levels in the experiments (Figure 2). The different piglet mortality rate shown for Pietrain and Duroc progeny was observed irrespective of litter size (TNB) and no relation between TNB and MORT 21 was found on boar level (Figure 3).

Low mortality rate is important for the commercial pig production to increase productivity and to increase animal welfare. The different survival rate of progeny from the two sire lines of Duroc and Pietrain showed that breeds might be different and that choice of breed can be a useful tool to increase animal welfare. Since the breeds were obtained from different breeding programs, it furthermore demonstrates that breeding can be a useful tool to increase animal welfare (Kanis et al., 2004).

In summary, the farrowing rates were on the same level for the two terminal sire lines obtaining a level at 92% for both breeds. Use of Pietrain boars as the terminal lines led to higher TNB than use of Duroc boars obtaining 18.7 and 18.2 TNB per litter, respectively. The Duroc progeny showed higher survival rate than Pietrain sire progeny. The LS5 and LS21 for D-litters were even higher than for P-litters. At day 21 after birth, the mean litter size in P- and D-litters were 14.5 and 14.9 piglets per litter, respectively. The mean mortality rate obtained as means of the mortality rates in all litters during the suckling period, including still born piglets, ranged from 19.5% to 23.6% and from 17.6% to 19.1% in P- and D-litters, respectively. The service sire variances of litter size, i.e., TNB, LS5, and LS21 ranged between 3.8% and 5.3% with the highest variation in TNB.

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