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Production traits of litters in 2 crossbred Duroc pig lines

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ABSTRACT: Genetics of different pig lines affects litter size, birth weight, and neonatal losses. Low birth weight has long been associated with neonatal losses, but piglet body mass index is reported to show stronger correlation with stillbirth. The aim of this study was to investigate differences in litter size, number of stillborn piglets, piglet BW gain, and body mass index between 2 different Duroc crossbred lines. Landrace × Yorkshire sows in 2 farms (n = 89) were divided into 2 groups on each farm. One group of sows on each farm was inseminated with semen from Landrace × Duroc boars (boar group LD, n = 48), and the other was inseminated with semen from purebred Duroc boars (boar group DD, n = 41). Piglets were monitored from birth to weaning at the age of 5 wk. Litter size in boar group LD was larger than in boar group DD ($P = 0.03$). Number of stillborn piglets in boar group LD tended to be greater than in boar group DD ($P = 0.07$). Piglets in boar group DD had a greater BW at birth ($P = 0.02$) and at 3 wk ($P = 0.01$) than those in boar group LD. Body mass index from birth to weaning was greater in piglets in boar group DD vs. LD ($P < 0.01$), and both BW and body mass index of liveborn piglets at birth for both groups combined showed a positive correlation with survival at weaning ($P < 0.01$). In conclusion, breeding for larger litter size in boar group DD may be one approach to increase the number of vigorous piglets in production, but the inverse relationship between litter size and birth weight was more pronounced for this group than for boar group LD ($P = 0.03$). Further studies of the impact of litter size on BW gain are necessary before a final conclusion can be reached.

Key words: body mass index, body weight gain, Duroc, neonatal loss, pig, stillbirth

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INTRODUCTION

Neonatal qualities can determine economic profitability in porcine production. Large litter size combined with few neonatal losses and large daily piglet BW gain are important production goals. Although managerial factors are probably most important with respect to minimizing neonatal losses (Munsterhjelm et al., 2006; Andersen et al., 2009; Oliviero et al., 2010), genetic factors also have been shown to significantly influence this variable (Leenhouwers et al., 2003; Roehe et al., 2010; Vanderhaeghe et al., 2010). Studies have indicated that birth weight is not necessarily positively correlated with physiological maturity at birth (Herpin et al., 1993; Leenhouwers et al., 2002). In accordance with this, it has been shown that piglet body mass index (**BMI**) may be a better predictor of the probability of live birth than birth weight (Baxter et al., 2008).

The heritabilities of litter traits such as litter size, neonatal loss, and birth weight are low (0.15, 0.05, and 0.06, respectively) and decline further if the selected population becomes homozygous for alleles controlling these traits. Still, genetic variation between breeds is sufficient such that litter traits can be improved through selective breeding (Tamarin, 1999; Chen et al., 2003; Su et al., 2007). In Norway, the mean litter size and mean number of weaned piglets for the purebred Landrace breed are 14.2 and 10.3, respectively. Corresponding figures for the purebred Duroc (**DD**) are 9.8 and 7.3, and for crosses between Landrace × Yorkshire (**LY**) sows bred with Landrace × Duroc (**LD**) boars are 14.2 and 11.0 (Ingris Animalia Norsvin, 2011).

The aim of the present study was to investigate whether litter size, number of stillborn piglets, and piglet BW gain up to weaning differs between litters from LY sows inseminated with semen from DD boars vs. LD boars. The difference in piglet birth weight and piglet BMI between boar groups was also studied, as well as the association of piglet birth weight and piglet BMI at birth with postpartum survival.

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MATERIALS AND METHODS

The experimental protocol for this study did not require approval by the Norwegian Animal Research Authority because of an exception for such procedures in the Norwegian regulations for animal testing (FOR 1996-01-15 No. 23, Regulation of animal testing, §2: Scope).

Animals

Main Data Set. The LY sows (n = 89) in the same sow pool system, and all originating from the same multiplier herd, were divided into boar groups LD (n = 48) and DD (n = 41). Sows in boar group LD were inseminated with semen from LD boars, and sows in boar group DD were inseminated with semen from DD boars. Semen was randomly assigned to the sows at AI. In boar group LD, 9 of the sows were inseminated with heterospermic semen from unidentifiable boars. The remaining 39 sows in boar group LD and all the sows in boar group DD were inseminated with homospermic semen from 9 and 8 identifiable boars, respectively. All sows were inseminated by the same technician at standing estrus with 2 doses of 2.5×10^9 spermatozoa, 1 d apart. Gilts were loose housed in 1 group until 3 wk before farrowing, and older sows were loose housed in another group. At this time point, 19 sows in boar group LD and 17 sows in boar group DD were transported to farm 1, and 29 sows in boar group LD and 24 sows in boar group DD were transported to farm 2.

Subset. Eighteen nonrandomly selected sows at farm 1 had additional individual recordings during the farrowing process. Both boar groups were equally represented with 9 litters each in this subset. In boar group LD, 2 of the sows had been inseminated with heterospermic semen from unidentifiable boars, whereas the remaining sows in this subset and all the sows in the boar group DD subset had been inseminated with homospermic semen from 6 identifiable boars in each group.

Management

All sows were kept individually and without fixation in standard farrowing pens without crates (7.0 to 7.3 m^2) with a piglet creep area (0.8 to 1.3 m^2) from 3 wk before expected farrowing until weaning. Each pen had a solid floor except for a slatted drainage floor at one end of the pen (2.3 m^2). A commercial lactation diet (9.86 MJ of NE·kg^{-1}, 8.26 g of lysine·kg^{-1}) was offered twice daily to the sows until 1 wk postpartum, when the frequency was increased to 3 times daily at farm 1 (dry feed) and 4 to 5 times daily at farm 2 (liquid feed). All sows were given small amounts of hay. Sows and piglets had ad libitum access to water. Farrowing was allowed to occur naturally, although under constant surveillance by the staff. Newborn piglets had access to the heated piglet creep area, which was inaccessible to the sow and was bedded with sawdust. The piglets were offered a commercial pelleted piglet dry feed (Kvikk 1, Felleskjøpet, Oslo, Norway) from 1 wk of age. The feed was offered on iron-enriched peat (Pluss Smågristorv, Felleskjøpet Fòrutvikling, Trondheim, Norway). Commercial husbandry procedures included ear tagging of each piglet, tooth grinding, and oral administration of 200 mg of supplemental iron (Format, Felleskjøpet, Oslo, Norway), all at 1 d postpartum. Cross fostering to ensure a functional teat for each piglet was permitted within the same boar group. This was performed in 4 LD litters and in 3 DD litters the day after birth, with a total of 1.5% of all piglets. One LD litter of 12 piglets was also cross-fostered to an artificial plastic sow (Mambo, Husdyr Systemer As, Mosby, Norge) with milk replacer (Sprayfo Pork, Husdyr Systemer As, Mosby, Norge) from 3 wk of age, and therefore excluded from the study from this time point. All male piglets were surgically castrated under local anesthesia by a licensed veterinarian before 14 d of age.

Data Collection

Main Data Set. The sows were grouped into 3 categories according to parity number: primiparous sows, sows of parities 2 and 3, and sows of parity 4 or greater. Litter size at birth and number of stillborn piglets were recorded. Litter size was later defined as the number of piglets in the pen, regardless of whether or not cross-fostering had occurred. Litter weight with stillborn piglets included was obtained within 24 h postpartum and before cross fostering. Individual BW was obtained at 3 wk (18 to 26 d) and at weaning (29 to 43 d). Exact age in days when individual BW were recorded was termed age at weighing. Litter sizes at 3 wk and at weaning were also recorded. Stillbirth was defined as a piglet born without respiration, as assessed by trained staff or a veterinarian. Necropsies were not performed, and mummified piglets were excluded from the study. The study was performed over the course of a 6-wk period starting in June 2009.

Subset. Each piglet in the subset was weighed and had body length measured from the os occipitale to the root of the tail at birth, 10 to 12 d, 3 wk (20 to 22 d), and at weaning (32 to 40 d). Body weight and length were used for calculation of BMI [BW (kg)/length (m^2)] for each piglet.

Statistical Analyses

Main Data Set. Analyses at the sow level were performed using GLM of JMP 8 (SAS Inst. Inc., Cary, NC). Differences in the outcome variables of litter size at birth, stillborn piglets per litter, litter weight at birth, litter size at 3 wk, and litter size at weaning were compared among the explanatory variables boar group, parity group, and farm. Similarly, the outcome of litter weight at weaning was assessed in a GLM, with age at weighing included as an additional explanatory variable. A backward elimination procedure was used, and only explanatory variables with an association with the outcome variables yielding a *P*-value <0.10 were included in the final model. Consequently, parity group was omitted as an explanatory variable from the models assessing litter size at 3 wk and litter size at weaning, and farm was omitted from all analyses except for the models assessing litter weight at birth and litter weight at weaning. Boar group was forced into all 6 models for the comparisons.

Analyses at the piglet level were performed using GLM with sow included as a random effect to account for clustering at the sow level using Stata SE11 (xtreg, StataCorp LP, College Station, TX). Differences in the outcome variables of piglet weight at 3 wk and weaning were compared among the explanatory variables boar group, parity group, litter size at age of weighing, age at weighing, and farm. A backward elimination procedure was used, and only explanatory variables with an association with the outcome variables yielding a *P*-value <0.10 were included in the final model. Consequently, parity group and farm were omitted from the final model assessing piglet weight at 3 wk. Boar group was forced into both models for the comparisons.

Subset. Analyses at the piglet level were performed using GLM with sow included as a random effect to account for clustering at the sow level using Stata SE11 (StataCorp LP). Differences in the outcome variables of birth weight and BMI at birth, 10 to 12 d, 3 wk, and weaning were compared among the explanatory variables of boar group, parity group, and litter size at birth. For birth weight, the interaction term boar group × litter size was also included. A backward elimination procedure was employed, and only explanatory variables with an association with the outcome variable yielding a *P*-value <0.10 were included in the final model. Consequently, parity group was omitted from the analyses for birth weight, whereas all explanatory variables other than boar group were omitted from the final models for the assessment of BMI. One litter of 5 piglets in boar group LD was regarded as being nonrepresentative due to small litter size and, subsequently, was excluded from the analyses of the subset. However, the analyses were also run with this litter included for comparison.

Analyses of difference in the outcome variables of birth weight and BMI at birth of all live-born piglets pooled and the association with survival at weaning were performed using 1-way ANOVA with JMP 8 (SAS Inst. Inc.).

Overall statistical significance of the models was assessed by the type-III *F*-test in JMP or the Wald χ^2 in Stata SE11. The R^2 statistic was also used to assess predictions from the regression equations. Homoscedasticity and normality of the residuals were assessed using plots of standardized residuals. In all analyses, statistical significance was considered as $P < 0.05$.

RESULTS

Main Data Set

Parity number ranged from 1 to 8 in both sow groups and 24 out of 89 sows were primiparous (i.e., 14 in boar group LD vs. 10 in boar group DD). Median parity number was 3 in both groups. In total, 1,386 piglets were born, of which 784 were in boar group LD and 602 in boar group DD. The difference in litter size between homospermic (16.1 piglets) and heterospermic (14.6 piglets) inseminations was tested univariately and found not to be different ($P = 0.27$).

Associations at birth between the outcome variables of litter size, stillborn piglets per litter, and litter weight, and the explanatory variables of boar group, parity group, and farm are presented in Table 1. The association between stillborn piglets per litter and boar group also was solved for the least significant number in a univariate ANOVA. A significance level of $P < 0.05$ was obtained when the sample size was increased to 118, as opposed to 89 litters ($P = 0.07$) in the current investigation.

Mean litter size at 3 wk of age was 11.56 (SE = 0.21) for boar group LD and 11.10 (SE = 0.23) for boar

Table 1. Associations at birth between litter size, stillborn piglets per litter, and litter weight and the explanatory variables boar group, parity group, and farm

	Litter size		Stillborn piglets per litter		Litter weight, kg	
Variable	β (SE)	*P*-value	β (SE)	*P*-value	β (SE)	*P*-value
LD[1]	0.84 (0.38)	0.03	0.28 (0.15)	0.07	0.33 (0.52)	0.52
DD[2]	—	—	—	—	—	—
Parity 1	—	—	—	—	—	—
Parity 2 and 3	−0.65 (0.52)	0.21	−0.35 (0.21)	0.09	0.35 (0.71)	0.62
Parity >3	1.86 (0.52)	<0.01	0.69 (0.21)	<0.01	1.71 (0.72)	0.02
Farm 1	—	—	—	—	—	—
Farm 2	—	—	—	—	0.92 (0.52)	0.08
Intercept	14.90 (0.38)	<0.01	1.83 (0.15)	<0.01	21.46 (0.53)	<0.01

[1]LD = boar group Landrace × Duroc (n = 48).

[2]DD = boar group Duroc × Duroc (n = 41).

Table 2. Associations between piglet weight at 3 wk and at weaning and the explanatory variables boar group, parity group, litter size, exact age in days, and farm

	Piglet BW at 3 wk, kg		Piglet BW at weaning, kg	
Variable	β (SE)	P-value	β (SE)	P-value
LD[1]	−0.48 (0.19)	<0.01	−0.37 (0.27)	0.17
DD[2]	—	—	—	—
Parity 1	—	—	—	—
Parity 2 and 3	—	—	1.11 (0.34)	<0.01
Parity >3	—	—	0.90 (0.34)	<0.01
Litter size[3]	−0.13 (0.06)	0.04	−0.26 (0.09)	<0.01
Exact age	0.34 (0.05)	<0.01	0.33 (0.05)	<0.01
Farm 1	—	—	0.63 (0.27)	0.02
Farm 2	—	—	—	—
Intercept	1.46 (1.17)	0.21	1.80 (1.76)	0.31

[1]LD = boar group Landrace × Duroc. A litter of 12 was fostered by an artificial plastic sow from 3 wk of age and excluded from these models (n = 555 at 3 wk and 550 at weaning).

[2]DD = boar group Duroc × Duroc (n = 455).

[3]Litter size at weighing.

group DD ($P = 0.14$). Mean litter size at weaning was 11.46 (SE = 0.22) for boar group LD and 11.10 (SE = 0.23) for boar group DD ($P = 0.26$). Among all piglets born in boar group LD, stillborns included the following: 72.3% (n = 567) of the piglets were alive at 3 wk of age vs. 75.6% (n = 455) in boar group DD. At weaning 71.7% (n = 562) of the piglets were alive in boar group LD vs. 75.6% (n = 455) in boar group DD. Of all liveborn piglets in boar group LD, 18.3% (n = 126) had died by weaning vs. 16.2% (n = 88) in boar group DD.

The LS means for litter weight at weaning were 124.11 kg (SE = 2.79) for boar group LD and 126.42 (SE = 3.00) kg for boar group DD ($P = 0.58$). Litter weight at weaning increased by 4.28 kg each day that weighing was delayed ($P < 0.01$). Compared with first-parity sows, litter weight was numerically 4.89 kg (SE = 2.76) greater in sows of parities 2 and 3 ($P = 0.08$), whereas older sows produced litters that were not different from first-parity sows ($P = 0.75$). Associations between piglet weight at 3 wk and at weaning and the explanatory variables boar group, parity group, litter size, age in days, and farm are presented in Table 2. Estimated BW for piglets in boar group LD and parity group 2, in an average litter of 11 piglets at 21 d, was 6.9 kg, whereas a corresponding estimate for DD piglets was 7.4 kg. Similar estimates at 35 d in farm 2 were 11.5 and 11.9 kg, respectively.

Subset

In total, 261 piglets were included in the subset, of which 139 were in boar group LD and 122 were in boar group DD. Associations between piglet birth weight and the explanatory variables boar group, litter size, and the interaction term litter size × boar group are presented in Table 3. Estimated birth weight for piglets in boar group LD in a litter of 11 piglets was 1.3 kg, compared with 1.7 kg for piglets in boar group DD. Similar estimates for a litter size of 14 piglets were 1.3 and 1.5 kg, respectively. Birth weight was negatively correlated with litter size, and the regression of birth weight on litter size and boar group showed a significant interaction effect. Thus, the rapid decrease in the birth weight of piglets with increasing litter size in boar group DD was less marked in piglets in boar group LD. The assessment of variance components showed that 21% of the total unexplained variance in birth weight resided at the sow level. Inclusion of the litter with only 5 piglets yielded the following significance levels: boar group, $P = 0.24$; litter size, $P < 0.01$; and for the interaction, $P = 0.30$.

Associations between BMI and boar group at birth, 10 to 12 d, 3 wk, and at weaning are presented in Table 4. Mean BMI at birth was 21.2 (SE = 0.20) for all liveborn piglets pooled that survived to weaning (n = 183) vs. 19.4 (SE = 0.49) for piglets that did not survive (n = 31; $P < 0.01$). Mean birth weight for the same groups was 1.45 kg (SE = 0.03) for survivors vs. 1.23 kg (SE = 0.05) for nonsurvivors ($P < 0.01$).

Table 3. Associations between piglet birth weight and the explanatory variables boar group, litter size, and the interaction term between boar group and litter size

	Piglet birth weight, kg	
Variable	β (SE)	P-value
LD[1]	−1.15 (0.48)	0.02
DD[2]	—	—
Litter size at birth	−0.07 (0.02)	<0.01
Subset LD × litter size	0.07 (0.03)	0.03
Intercept	2.42 (0.31)	<0.01

[1]LD = boar group Landrace × Duroc. A litter of 5 piglets was considered an outlier due to small litter size and excluded in this model (n = 110).

[2]DD = boar group Duroc × Duroc (n = 116).

Table 4. Associations between body mass index (BMI) at birth, 10 to 12 d, 3 wk, and weaning and the explanatory variable boar group[1]

	BMI birth	BMI 10 to 12 d	BMI 3 wk	BMI weaning
Boar group	β (SE)	β (SE)	β (SE)	β (SE)
LD[2]	19.8 (0.69)	29.9 (0.74)	33.5 (0.76)	35.6 (0.70)
DD[3]	21.9 (0.48)	32.7 (0.51)	36.2 (0.52)	37.8 (0.49)

[1]Means within each column differ between boar groups ($P < 0.01$).

[2]LD = Landrace × Duroc (n = 104 at birth, 90 at 10 to 12 d, 89 at 3 wk, and 96 at weaning).

[3]DD = Duroc × Duroc (n = 105 at birth, 91 at 10 to 12 d, 90 at 3 wk, and 91 at weaning).

DISCUSSION

Litter size at birth was significantly larger in boar group LD vs. DD and corresponds with a larger litter size in purebred Norwegian Landrace pigs vs. purebred Duroc pigs (Ingris Animalia Norsvin, 2011). The difference was smaller than between the 2 pure breeds and may be a result of the genetic difference only on the boar side. More stillborn piglets would consequently be expected in boar group LD because stillbirth is positively correlated with litter size (Boulot et al., 2008; Andersen et al., 2011). In our study, this difference approached significance. A decrease in stillborn piglets close to 1 in 3 piglets per birth event in boar group DD is nevertheless interesting and should be viewed as an opportunity to improve animal welfare in pig production.

Litter weight was not significantly different between boar groups at birth or at weaning. Because litter weight is affected by both litter size and individual piglet weight and both were significantly different between boar groups, a direct comparison is not possible. The heavier individual birth weights in boar group DD correspond to a greater survival rate in the same group. This is supported by several studies in which birth weight was found to be positively correlated with postpartum survival (de Passillé et al., 1993; Tuchscherer et al., 2000; Milligan et al., 2002). Birth weight was negatively associated with increasing litter size in both boar groups, which is in accordance with reports from other studies (Boulot et al., 2008; Beaulieu et al., 2010). Furthermore, a litter size × breed interaction was found, and birth weight was more greatly reduced by increasing litter size in boar group DD than in boar group LD.

Piglet placentas are of fetal origin (Senger, 2003; McGeady et al., 2006), and boar consequently has a genetic effect on the fetal placenta (Fowden et al., 2006; Liu et al., 2010; L'abée et al., 2011). Larger birth weight and BW gain for the first 3 wk of life in boar group DD indicated that piglets of DD boars may not only be phenotypically larger, but also have a genetic potential for larger birth weights and BW gain than piglets of LD boars. However, the steeper decrease in mean birth weight with increasing litter size in this boar group may indicate a placental property that sustains functionality less effectively as litter size increases. Because the sows in this study were of the same breed, these group differences suggest a boar effect.

Genetic selection in purebred Duroc pigs in Norway has mainly focused on BW gain, feed conversion rate, and meat qualities. Selection for litter properties has only recently been a consideration in breeding goals for this breed (Bjarne Holm, Norsvin, Hamar, Norway, personal communication) and may partly explain these results. However, in these analyses, litter size at birth ranged from 10 to 18 in boar group LD, and from 14 to 21 in boar group DD. Because litter size did not completely overlap between groups, predictions were conducted slightly outside the range. Interpretation of the results should therefore be made with caution and investigated further before reaching a definitive conclusion. Further study on placental significance for piglet vitality is also suggested as a research priority.

The significantly heavier BW of piglets in boar group DD at 3 wk of age is in accordance with results from other studies showing that BW gain is positively correlated with birth weight (Herpin et al., 1996; Johansen et al., 2004; Beaulieu et al., 2010). In many countries, piglets are weaned at 3 wk of age. A heavier weaning weight is associated with greater BW gain after this time point (Bruininx et al., 2001). Thus, the period between birth and achieving commercial slaughter weight is reduced. Three weeks of age is also a relevant time point to collect data in swine production because piglet BW gain after the age of 3 wk is more influenced by differences in milk production and consumption of creep feed than before this time point (Pluske et al., 1995).

Litter size at weaning was not significantly different between boar groups. Litter size at weaning is affected by the number of liveborn piglets and neonatal loss. Because neonatal loss was more than 2% greater in boar group LD vs. DD, the difference recorded at birth was reduced. For the sow, the feeding, housing, and managerial costs are approximately the same, regardless of the number of piglets being weaned. For the piglets, a greater number being weaned may require larger areas and managerial costs, but additional feeding cost to weaning is relatively limited (Pajor et al., 1991; Pluske, 1993). Thus, it seems advisable to breed for increased vitality and survival of the piglets and also to breed for those sow properties that improve the capabilities of caring for the offspring. In addition to the positive animal welfare aspect of breeding for increased survival, the financial profit could be substantial because the sale of food products from ethically approved swine production systems may increase. Ethical concerns regarding neonatal deaths in swine production will probably be of more importance for consumers in the future (Gregory, 2007). Thus, in competing with other meat products for human consumption on the market, animal welfare should be a subject of greater focus.

Piglet BMI at birth is reported to be more closely related to survival at birth than birth weight (Baxter et al., 2008). Interestingly, the greatest BMI in this study, both at birth and throughout the study period, was found in boar group DD. Increasing BMI, as was noted at all 4 recording periods, seems favorable in a production animal because it is a measure of the balance between length and weight. This, in combination with the significant association between increased BMI at birth for both boar groups pooled and survival at weaning, suggests that breeding for BMI may be beneficial for animal welfare, as well as for economic issues. Heavier piglets and reduced neonatal loss, as registered in boar group DD compared with boar group LD, may be a reflection of animal welfare parameters and should be given consideration when deciding on future breeding goals in swine production.

In conclusion, having larger piglets from smaller litters with fewer neonatal losses reflects that piglets in boar group DD are more vital than piglets in boar group LD. Litter weight at weaning, although not significant, was numerically greater in boar group DD. Animal welfare aspects of piglets in boar group DD, therefore, seem to be superior to those in boar group LD. Breeding for larger litter size in boar group DD may consequently be one approach for increasing the number of vigorous piglets in production, but it should be noted that the inverse relationship between litter size and birth weight was more pronounced for this group than for boar group LD. The results of this study suggest that the LY × DD crossbreed is promising, but further studies are necessary before a final conclusion can be reached.

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