Evaluation of Duroc- vs. Pietrain-sired pigs for growth and composition

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ABSTRACT: Accurate evaluations of growth and composition traits enable better management decisions regarding genetic merit, feeding, and marketing. Sires from Duroc and Pietrain populations were used to produce crossbred pigs, which were evaluated for growth and composition traits. All parents were normal for the ryanodine receptor gene. Boars from each breed were mated to either Yorkshire or F1 Yorkshire-Landrace females with 307 offspring evaluated from birth through 26 wk of age. No significant differences between sire breeds were seen for pig BW from birth through 10 wk of age. Body weight, 10th rib backfat (BF10), last rib backfat (LRF), and loin muscle area (LMA) were serially measured at 10, 13, 16, 19, 22, 24, and 26 wk of age. At 26 wk of age, Duroc-sired progeny were heavier (143.4 vs. 132.7 kg, \( P < 0.001 \)), had more BF10 (27.1 vs. 23.7 mm, \( P < 0.001 \)) and LRF (21.2 vs. 19.2 mm, \( P < 0.001 \)), but had similar LMA (46.4 vs. 47.1 cm\(^2\)) compared with Pietrain-sired progeny. Mean feed efficiency did not differ between breed of sire in any period of the study. Duroc progeny had a greater Key words: body composition, breed, feed conversion, genetic parameter, growth, pig

INTRODUCTION

Breeds and lines used in commercial production systems differ in growth, composition, and meat quality. The Pietrain breed, which only recently has been used on an extensive basis in the United States, has been used and characterized in European production systems, but Pietrain pigs have been minimally evaluated in US production systems. Studies (Kanis et al., 1990; Affentranger et al., 1996; Garcia-Macias et al., 1996) have compared Pietrain-sired pigs with Duroc-sired pigs, but the wide range of final BW used has led to inconsistent results concerning differences between breeds for feed efficiency, growth, and composition.

Growth curves can be useful to describe an animal or population’s genetic potential for the time period considered and are an effective way to summarize measurement information into only a few parameters (Mignon-Grasteau et al., 1999). Change in body mass can be partitioned into its component parts. This partitioning provides more information concerning biological differences between animals within populations as well as further description of different populations.

Routine dissecting or chemically analyzing animals at different slaughter weights is cost prohibitive on a large number of pigs (Schinckel and de Lange, 1996). In addition, animals slaughtered would not be available for breeding purposes, which would allow only information on relatives to be used for predicting genetic merit. Serial live measurements, such as ultrasound measurements, allow functions of protein and fat accretion to be developed for pigs of differing genotypes. Accurate evaluations of growth and composition traits provide

\( \frac{266}{275} \)
Yorkshire and F1 Yorkshire-Landrace females within parity and breed classification subgroup were randomly assigned to be single sire mated artificially to either Duroc or Pietrain boars. Yorkshire and F1 Yorkshire-Landrace females were represented in each of the 4 genetic families to obtain a cross-section of different genetic families for growth traits measured.

Table 1 shows the number of pigs by sire breed, dam breed, and gender subclass at birth and subsequently put on-test. Birth date, birth BW, weaning BW, and lactation length (mean of 24.7 d of age) were recorded.

At weaning, pigs were sorted into sire breed, gender, and BW subgroups and were randomly assigned within subgroups to nursery pens (mean of 9.8 pigs per pen). Pigs were provided diets on an ad libitum basis that met or exceeded nutritional requirements (NRC, 1998) for each nursery production phase. Pig BW were taken at 6 wk of age and again at 10 wk of age. After 10 wk of age, pigs (307 total, Table 1) within 2 standard deviations of the mean weight within replication were put on test in a grow-finish facility and randomly assigned to pens in groups of 4 sorted by sire breed, gender, and BW. The grow-finish building was an open-fronted, bedded facility with sloped solid concrete floors and 1.75 m² minimum pen space per pig. Pigs were provided diets ad libitum to allow maximum growth potential. Diets were formulated for the finisher phase for 3 weight ranges; from 23 to 57 kg, from 57 to 113 kg, and from 113 kg to market. These diets were formulated to contain 3,411, 3,427, and 3,394 kcal/kg, respectively, with lysine levels at 1.00, 0.90, and 0.75%, respectively. Pig BW and B-mode ultrasound (Pie Medical 200SLC; Classic Medical Supply, Inc., Tequesta, FL) estimates of off-midline backfat at the 10th rib (BF10), off-midline last rib fat (LRF), and loin muscle area at the 10th rib (LMA) were taken at 10, 13, 16, 19, 22, 24, and 26 wk of age. Pigs were scanned by a National Swine Improvement Federation certified ultrasound technician. During nursery and grow-finish phases of growth, feed disappearance was measured on a pen basis to calculate the ratio of feed to BW gain (feed efficiency). At the end of the grow-finish period (approximately 26 wk of age), pigs near the mean weight within gender of each litter (162 total) were slaughtered and carcass measurements and meat quality assessment completed (Edwards et al., 2003).

### Growth Response Variables

Pig BW at birth, weaning (3 wk of age), 6 wk of age, 10 wk of age, and 26 wk of age were analyzed along with BF10, LRF, and LMA at 26 wk of age. In addition, ADG from 10 to 26 wk of age was calculated. Least squares estimates of all marginal means were calculated using the following model:

\[
Y_{ijklm} = \mu + \text{bos}_i + \text{bod}_j + \text{rep}_k + \text{sex}_l + \text{bos}^*\text{rep}_k + \text{bos}^*\text{sex}_l + g_m + \beta x_{ijklm} + e_{ijklm},
\]

in which

\[
Y_{ijklm} = \text{record on the pig m within the sire breed i, dam breed j, farrowing group k, and gender l},
\]

\[
\mu = \text{overall mean of trait},
\]

\[
\text{bos}_i = \text{fixed effect of sire breed i (Duroc or Pietrain)},
\]

\[
\text{bod}_j = \text{fixed effect of dam breed j (Yorkshire or F1 Yorkshire-Landrace)},
\]
rep_k = fixed effect of farrowing group k (1, 2, 3, or 4),
sex_l = fixed effect of gender l (barrow or gilt),
bos*rep_i = interaction of fixed effects of sire breed i and farrowing group k,
bos*sex_ij = interaction of fixed effects of sire breed i and gender l,
g_m = random effect of animal m,
xijklm = covariate(s) appropriate to each trait such that \( \beta \) is the partial regression coefficient on xijklm, and
eijklm = random error ~ N(0, \( \sigma^2_e \)).

Here, \( g = \{g_m\} \sim N(0, A\sigma^2_g) \), in which \( A \) is the numerator relationship matrix among animals such that \( \sigma^2_g \) is the additive genetic variance. The relationship matrix accounted for relationships among progeny plus the 3 generations of sire ancestors and 2 generations of dam ancestors. Preliminary analyses included a random effect of pen nested within replicate, breed of sire, and gender. However, because of penning strategies employed in this study, pen effects were confounded and could not be estimated.

The covariate used for birth BW was number of pigs born in the litter. For traits other than birth BW, a covariate to adjust for age at measurement was used. For weaning BW, number of pigs weaned from each litter was also used as a covariate. The covariate for 10 to 26 wk ADG was the age at the 10-wk weighing. Breed of dam was significant only for BW prior to 10 wk of age. Interaction terms with \( P < 0.20 \) were kept in the model. Feed efficiency was analyzed on a pen basis using a model with fixed effects of farrowing group, breed of sire, and a term for interaction of breed of sire by gender.

**Random Regression Model Analysis**

Serial BW and ultrasound estimates from 10 to 26 wk of age were used to generate random regression equations to model pig BW, BF10, LRF, and LMA on age at measurement for individual animals. Additionally, measures of fat-free lean tissue (TOFATL), total fat tissue (TOFAT), empty body protein (EBPRO), and empty body lipid (EBLIPID) at different BW ranges were calculated using equations similar to those used by Wagner et al. (1999). These measures of fat deposition and protein accretion were modeled on age of measurement by random regression. Age at measurement was modeled as week on-test, calculated as age in weeks minus 9 (i.e., 1, 4, 7, 10, 13, 15, and 17 as distinct covariate values used in the analysis). A random intercept for each animal and a linear regression on age for each animal was included in each model. Main effects and interactions with \( P < 0.20 \) were kept in the model. The following model was used:

\[
Y_{ijklm} = \mu + \text{bos}_i + \text{sex}_j + \text{rep}_k + \text{week}_l + \text{bos*sex}_{ij} + \text{bos*rep}_{ik} + \text{bos*week}_{il} + \text{rep*week}_{kl} + \text{bos*sex*week}_{ijl} + g_m + \alpha_m Z_l + e_{ijklm},
\]

in which

\[
Y_{ijklm} = \text{record on the pig m within the sire breed i, gender j, farrowing group k, and week of age l},
\]

\[
\mu = \text{overall mean of trait},
\]

\[
\text{bos}_i = \text{fixed effect of sire breed i (Duroc or Pietrain)},
\]

\[
\text{sex}_j = \text{fixed effect of gender j (barrow or gilt)},
\]

\[
\text{rep}_k = \text{fixed effect of farrowing group k (1, 2, 3, or 4)},
\]

\[
\text{week}_l = \text{fixed effect of week of age l (10, 13, 16, 19, or 22)},
\]

\[
\text{bos*sex}_{ij} = \text{interaction of fixed effects of sire breed i and gender l},
\]

\[
\text{bos*rep}_{ik} = \text{interaction of fixed effects of sire breed i and farrowing group k},
\]

\[
\text{bos*week}_{il} = \text{interaction of fixed effects of sire breed i and week of age l},
\]

\[
\text{rep*week}_{kl} = \text{interaction of fixed effects of farrowing group k and week of age l},
\]

\[
\text{bos*sex*week}_{ijl} = \text{interaction of fixed effects of sire breed i, gender j, and week of age l},
\]

\[
g_m = \text{random effect of animal m},
\]

\[
\alpha_m = \text{random linear regression coefficient on age for animal m},
\]

\[
Z_l = \text{week on test as a covariate},
\]

\[
e_{ijklm} = \text{random error}.
\]

The distributional assumptions on \( g = \{g_m\} \) and \( \alpha = \{\alpha_m\} \) were such that:

\[
\begin{bmatrix} g \\ \alpha \end{bmatrix} \sim N \left( \begin{bmatrix} 0 \\ A\sigma^2_g \end{bmatrix} \right),
\]

in which \( \sigma^2_g \) is the intercept genetic variance for the individuals, \( \sigma^2_\alpha \) is the linear age by animal genetic variance, and \( \sigma_{\alpha g} \) is the genetic covariance between the intercept and linear term for each animal. To account for increasing residual variances across serial measurement and the relationship between time points, the \( e = \{e_{ijklm}\} \) was specified as normally distributed with a heterogeneous, autoregressive (co)variance structure specified within each animal over weeks. Utilizing genetic and residual (co)variances obtained for these 8 traits, heritability was calculated for each trait at each data point in a manner similar to that specified in Templeman et al. (2002).

**RESULTS AND DISCUSSION**

**Growth Estimates**

Least squares means, SEM, and significance levels for sire breed for response variables are listed in Table...
Table 2. Least squares means by breed of sire for BW, ultrasound estimates, ADG, and feed efficiency

<table>
<thead>
<tr>
<th>Trait</th>
<th>Duroc</th>
<th>Pietrain</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth BW, kg</td>
<td>1.7</td>
<td>1.7</td>
<td>0.07</td>
<td>0.205</td>
</tr>
<tr>
<td>3 wk BW, kg</td>
<td>7.8</td>
<td>7.6</td>
<td>0.31</td>
<td>0.723</td>
</tr>
<tr>
<td>6 wk BW, kg</td>
<td>15.0</td>
<td>14.6</td>
<td>0.57</td>
<td>0.244</td>
</tr>
<tr>
<td>10 wk BW, kg</td>
<td>31.7</td>
<td>31.0</td>
<td>1.03</td>
<td>0.262</td>
</tr>
<tr>
<td>26 wk BW, kg</td>
<td>143.4</td>
<td>132.7</td>
<td>1.50</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>26 wk BF10, mm</td>
<td>27.1</td>
<td>23.7</td>
<td>0.67</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>26 wk LRF, mm</td>
<td>21.2</td>
<td>19.2</td>
<td>0.51</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>26 wk LMA, cm²</td>
<td>46.4</td>
<td>47.1</td>
<td>0.52</td>
<td>0.908</td>
</tr>
<tr>
<td>10 to 26 wk ADG, g/d</td>
<td>980.1</td>
<td>892.3</td>
<td>11.30</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>10 to 26 wk FE, g/kg</td>
<td>319.1</td>
<td>323.3</td>
<td>2.84</td>
<td>0.307</td>
</tr>
</tbody>
</table>

BF10 = 10th rib backfat; LRF = last rib backfat; and LMA = loin muscle area; FE = feed efficiency.

2. No significant differences were detected between breed of sire for BW at birth, 3 wk, 6 wk, or 10 wk of age. A difference was seen for BW at 26 wk of age; Duroc-sired progeny were heavier than Pietrain-sired progeny ($P < 0.001$). Differences between sire breeds for BF10 and LRF were significant ($P < 0.001$); Duroc-sired progeny had more backfat at both locations. These results are in agreement with Kanis et al. (1990), who found that Duroc animals have more backfat than Pietrain animals at 60 kg (10.5 vs. 8.7 mm, respectively), at 100 kg (17.5 vs. 12.3 mm, respectively), and at 140 kg (24.4 vs. 17.4 mm, respectively). Similar results were also reported by Ellis et al. (1996); Duroc-sired progeny had fatter carcasses than Pietrain-sired progeny from pigs slaughtered at 80, 100, or 120 kg (overall mean C fat depths of 15.6 vs. 14.0 mm, respectively). Garcia-Macias et al. (1996) also reported more backfat measured between the third and fourth last rib (19.84 vs. 17.16 mm, respectively) for Duroc progeny vs. Pietrain progeny averaged across groups slaughtered at 90 or 120 kg.

Duroc- and Pietrain-sired progeny had similar loin muscle area at 26 wk of age, which differed from reports from other studies that Pietrain progeny have larger LMA [40.7 vs. 39.0 cm² (Ellis et al., 1996); 40.51 vs. 36.77 cm² (Garcia-Macias et al., 1996)] than Duroc-sired progeny. A heavier 26-wk BW for Duroc-sired progeny, coupled with similar 10-wk BW for pigs from each sire breed, led to Duroc-sired progeny with greater 10 to 26 wk ADG ($P < 0.001$), which was in agreement with Affentranger et al. (1996), who reported 20 g/d more BW gain in Duroc progeny compared with Pietrain progeny from 25 to 103 kg. These results contrasted with those of Ellis et al. (1996), who reported 764 g/d of ADG for Duroc progeny vs. 753 g/d for Pietrain progeny, which were not statistically different, and with the results of Kanis et al. (1990), who found greater ADG for Pietrain progeny vs. Duroc progeny (730 vs. 628 g/d, respectively). Least squares means by breed of sire for feed efficiency were calculated for each time period between dates on which animals were weighed. No significant differences were seen for feed efficiency over any of the time periods measured. In addition, overall efficiency of gain, calculated as grams of gain divided by kilograms of feed disappearance, also was not significant between 10 to 26 wk of age (319.1 vs. 323.3 g/kg) for Duroc- vs. Pietrain-sired progeny, respectively. Kanis et al. (1990) reported a difference in feed efficiency from 60 to 100 kg of BW (3.37 vs. 3.18 feed:gain for Duroc and Pietrain progeny, respectively), but no difference was reported from 100 to 140 kg (4.45 vs. 4.71, respectively) or for the entire test from 60 to 140 kg (3.89 vs. 4.00, respectively). Affentranger et al. (1996) reported lower feed conversion from 25 to 103 kg (2.75 vs. 2.59) for Duroc vs. Pietrain progeny.

Figure 1. Body weight estimates with SE from 10 to 26 wk of age by sire breed by gender subclass.
Random Regression Model Analysis

Parameter estimates for each of the 8 response variables modeled (BW, BF10, LRF, LMA, FFTOLN, TOFAT, EBLIPID, and EBPRO) were calculated for breed of sire by gender subclasses at each measurement point. Initial measures at the beginning of the test period for Duroc-sired barrows were greater, but nonsignificant ($P > 0.10$), for BF10 and LRF. Pietrain-sired gilts had greater, but nonsignificant ($P > 0.10$), initial measures of LMA and FFTOLN.

Graphs for each response variable were plotted by sire breed and gender subclasses with SE determined at each of the time points measured (Figures 1 through 8). These figures allow visualization of the data and realization of trends over time. At 10 wk of age, all progeny were similar in BW, but Duroc-sired barrows grew at a faster rate and were heavier at the end of the test ($P < 0.001$, Figure 1). Figures 2 and 3 (BF10 and LRF, respectively) indicate that Duroc-sired barrows had a greater rate of backfat deposition compared with the other breed of sire by gender subgroups. Loin muscle area (Figure 4) was similar at all points for all progeny, and rate of LMA accretion slowed as pigs reached 26 wk of age.

A linear animal by age term and, thus, genetic covariance between the animal term and the animal by age term were not fitted in the model for FFTOLN because...
of lack of model convergence. Similar to LMA, FFTOLN (Figure 5) had an equivalent rate of FFTOLN accretion for all progeny and slowed as pigs reached 26 wk of age. Throughout the test period all progeny had similar measures of FFTOLN. This disagrees with Kanis et al. (1990), who reported that Pietrain animals had a greater lean tissue growth rate than Duroc animals from 60 to 100 kg, but no difference was seen from 100 to 140 kg. A sigmoidal shape is apparent for TOFAT (Figure 6). All progeny started with similar amounts of TOFAT, but Duroc-sired barrows increased TOFAT at a greater rate than the other breed of sire by gender subclasses. All progeny had similar EBPRO (Figure 7) from 10 to 26 wk of age. All breed of sire by gender subclasses had similar EBLIPID (Figure 8) at 10 wk of age, but Duroc-sired barrows had more EBLIPID at 26 wk of age than any of the other three subclasses ($P < 0.001$).

At 26 wk of age, Duroc-sired barrows were heavier and had larger measures of BF10, LRF, TOFAT, and EBLIPID. Conversely, Pietrain-sired gilts were lighter and had smaller measures of BF10, LRF, TOFAT, and EBLIPID. Duroc-sired gilts and Pietrain-sired barrows had intermediate measures of these traits. Considering these differences in measures of fat and that LMA was not significantly different among the groups throughout

Figure 4. Loin muscle area estimates with SE from 10 to 26 wk of age by sire breed by gender subclass.

Figure 5. Fat-free total lean estimates with SE from 10 to 26 wk of age by sire breed by gender subclass.
the test, measures of FFTOLN and EBPRO were not different among the breed of sire by gender subclasses throughout the on-test period.

Estimates of heritability and SE were calculated for BW, BF10, LRF, LMA, FFTOLN, TOFAT, EBPRO, and EBLIPID from 10 to 26 wk of age. Heritability estimates for BW, BF10, LRF, and LMA are shown in Figure 9. All estimates started below 0.13 at 10 wk of age and generally increased through 26 wk of age. Heritability for BW was 0.05 at 10 wk of age and increased gradually until 0.38 at 26 wk of age, whereas BF10 and LRF started at 0.13 and 0.11, respectively, increased at a faster rate through the midpoint of the 10- to 26-wk-of-age period, and then leveled off to 0.76 and 0.79 at 26 wk of age, respectively. Solanes et al. (2004) reported 0.64 heritability for backfat on 100-kg pigs at slaughter, which was similar to our heritability estimates at comparable weights. However, this differs from 0.25 for ultrasound P2 fat depth heritability reported by Nguyen and McPhee (2005) for Large White pigs divergently selected for 6-wk postweaning growth rate. Heritability for LMA started at 0.15, then increased at a moderate rate, but did attain 0.73 by 26 wk of age. These increases in heritability from the
beginning to the end of the on-test period agree with the increasing nature of heritability in BW data in pigs modeled by random regression and reported by Huisman et al. (2002). Estimates for BF10 and LRF heritability were greater than that of LMA, which was greater than that of BW, agreeing with rankings of estimates reported for Duroc pigs by Chen et al. (2002). Kuhlers et al. (2003) reported heritabilities of 0.13 and 0.58 for BW and ultrasound backfat, respectively, of Duroc pigs at 168 d. This group also reported heritabilities of BW, ultrasound backfat, and loin eye area for Landrace pigs at 0.34, 0.56, and 0.47, respectively (Kuhlers et al., 2001). Figure 10 shows heritability estimates for FFTOLN, TOFAT, EBPRO, and EBLIPID. Heritability for FFTOLN decreased during the on-test period from 0.16 to 0.07. In contrast, TOFAT and EBLIPID estimates were 0.19 and 0.12, respectively, at 10 wk of age, increased quickly and early,

Figure 8. Empty body lipid estimates with SE from 10 to 26 wk of age by sire breed by gender subclass.

Figure 9. Heritability ($h^2$) from 10 to 26 wk of age for BW, 10th rib backfat, last rib fat, and loin muscle area.
Figure 10. Heritability ($h^2$) from 10 to 26 wk of age for fat-free total lean, total fat tissue, empty body protein, and empty body lipid.

...and then leveled off to 0.39 and 0.46, respectively, at 26 wk of age. Knapp et al. (1997) reported heritability of 0.40 for 100-kg Pietrain gilts for lean meat content (weight of ham, loin, and neck with fat layer removed in proportion to carcass weight). Additionally, Nguyen and McPhee (2005) reported heritability of carcass lean percentage of 0.40. Estimates for heritability for EMPRO started very low, 0.02 at 10 wk of age, but increased at a moderate rate to 0.55 at 26 wk of age. These heritability estimates fall in the low range for FFTOLN, moderate range for BW, TOFAT, EBPRO, and EMLIPID, and high range for BF10, LRF, and LMA.

**IMPLICATIONS**

Accurate evaluation of growth and composition traits is essential to decision making within production and marketing programs. Single time point (e.g., backfat at a certain age) and summary estimates (e.g., ADG over a time period) of characteristics that occur over time are useful; however, they will not properly distinguish nuances that occur over time. Serial measurement and random polynomial modeling can further distinguish subtle differences between breeds and lines that occur during the growth phase.

Both Duroc and Pietrain breeds can be useful in different breeding schemes. As market weights increase, progeny from both breeds will have similar amounts of fat-free total lean. Duroc-sired progeny have faster BW gain, whereas Pietrain-sired progeny grow more slowly with less fat accumulation. Other considerations, including meat quality traits, should also factor into choosing terminal sires.

**LITERATURE CITED**


