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Estimation of genetic parameters for performance and body measurement traits in Duroc pigs selected for average daily gain, loin muscle area, and backfat thickness☆

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ABSTRACT

Genetic parameters for performance and body measurement traits were estimated from a new line of purebred Duroc pigs selected during nine generations for average daily gain (ADG), loin muscle area (LMA), and backfat thickness (BF). Two animal models, which included or excluded the litter common random effect, were used to estimate genetic parameters. Common litter effects on most body measurement traits as well as performance traits proved to be important. Heritability estimates for body measurement traits ranged from 0.13 to 0.44. The genetic correlations among body length, withers height, chest depth, and hip height were estimated to be positive (0.17–0.86). Those among fore width, chest width, and hind width were also estimated to be positive (0.23–0.83). There were negative genetic correlations between the former and the latter traits (–0.82 to –0.30). Numerous genetic correlations between performance and body measurement traits were found to be favorable from medium to high. Our results indicate that selection using body measurement traits which have favorable genetic correlations such as chest width for ADG (0.39), hind width for LMA (0.32), and chest girth for BF (0.60) may be useful for improving performance traits.

1. Introduction

Exterior appraisal has been used as an indicator to improve slaughter characteristics (Van Steenbergen, 1989) or longevity (López-Serrano et al., 2000) in pigs. Genetic parameters for exterior traits have been studied previously (Van Steenbergen et al., 1990; López-Serrano et al., 2000; Tarrés et al., 2006). On the other hand, although records of body measurement traits are more difficult to obtain, they are more objective than exterior traits scored on a scale. Although records of body measurement traits are more difficult to obtain, they are more objective than body structure traits scored on a scale.

For body measurement traits, heritability estimates for body length (**BL**) related to carcass length as a performance trait in Duroc pigs (Fukawa et al., (2001), in Landrace pigs (Ishida et al., 2001), and in Landrace, Large White, Duroc, and Hampshire pigs (Johnson & Nugent III, 2003) have been reported to be moderate to high. Johnson and Nugent III (2003) found a negative relationship between BL and loin muscle area (**LMA**) at constant weight and age, implying that longer pigs had smaller LMA. However, there appears to be little published information on body measurement traits, except on BL, in pigs. Relationships between body measurement traits and performance traits are also not clear in pigs.

The objectives of this study were 1) to compare two animal models with and without common litter effect included; 2) to estimate genetic parameters for body measurement and performance traits; and 3) to estimate genetic trends for body measurement and performance traits from Duroc pigs selected for average daily gain (ADG), LMA, and BF.

2. Materials and methods

2.1. Animals and management

All procedures involving animals were performed in accordance with the National Livestock Breeding Center's guidelines for care and use of laboratory animals.

Data from a selected Duroc line were used for the analyses. The line was completely closed in 1995, and since then it has been selected for relative desired changes for ADG from 30 to 105 kg, LMA, and BF. LMA and BF were measured on the left side at 9 cm from the position of half body length at 105 kg of body weight using ultrasound (B-mode)

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equipment (USL-11, Kaijo-denki Co., Ltd., Tokyo).

The Duroc pigs had been selected over nine generations without overlapping at the Japan National Livestock Breeding Center's Miyazaki Station. The data set used for analysis consisted of 2,015 pigs for performance traits and 2,127 pigs for pedigree information.

Twenty-one boars and 86 gilts from six breeders in Japan and the United States were used to expand the population and produce the base population (G1). The population size of each generation was 25 boars and 90 gilts from the first parity. Pigs were weaned at three weeks of age and reared in growing pens. For each generation, one male piglet and two female piglets in each litter were selected as candidates for boars and gilts on the basis of their number of teats (no fewer than 6 pairs) and heavier individual body weights at 60 days of age. After that, about 90 boars and 180 gilts of each generation were reared when the animals reached a body weight of 105 kg, they were measured for BL, withers height (**WH**), hip height (**HH**), fore width (**FW**), chest width (**CW**), hind width (**HW**), chest depth (**CHD**), chest girth (**CHG**), and cannon circumference (the narrowest part of the left foreleg: **CNC**). Animals were selected by restricted BLUP of breeding values for ADG, LMA, and BF at body weight of 105 kg according to the methods laid out in the following chapter. After selection, each selected boar was randomly mated, avoiding full- and half-sib and cousin matings, to three or four selected gilts. Boars were retained for use during the 2-month breeding period. Animals were only mated within the same generation.

Pigs were provided *ad libitum* access to commercial feed (75% totally digestible nutrients (TDN) and 12.15% digestible crude protein (DCP) during the testing periods from 30 to 105 kg live weight. Pigs also had free access to water. After weaning, four pigs of each sex were reared in a growing pen and group-fed in a concrete-floored building. Each pen allowed 2.3–2.6 m^2 floor space per pig.

2.2. Selection method

The objective of this experiment was to produce a Duroc line to be used as terminal sires to improve performance traits. These Duroc boars would subsequently be supplied to pork producers as commercial terminal sires. Selection was conducted without a control line due to the limited accommodation ability of the facilities. Table 1 shows base population mean and breeding goal for selected traits. The relative desired gains were therefore + 191 g/day, + 2.5 cm^2, and ± 0 cm for ADG, LMA, and BF. The reason for the lack of change in BF is that Japanese pork markets do not like over-thin backfat.

Selection was performed once a year in the same season and animals were evaluated using restricted BLUP of breeding values on the basis of relative desired changes (Quaas & Henderson, 1976). The following animal model was used: $\mathbf{y} = \mathbf{Xb} + \mathbf{Zu} + \mathbf{e}$, where $\mathbf{y}$ represents the vector of observations; $\mathbf{b}$ is the vector of fixed effects (generation and sex effects); $\mathbf{u}$ is the vector of random additive genetic effects of animals, which is assumed to be distributed across $N(\mathbf{0}, \mathbf{G})$, where $\mathbf{G} = \mathbf{G}_0 \otimes \mathbf{A}$, $\mathbf{G}_0$ is the additive genetic variance-covariance matrix of an individual and $\mathbf{A}$ is the additive genetic relationship matrix among animals; $\mathbf{e}$ is the vector of residual effects, which is assumed to be distributed across $N(\mathbf{0}, \mathbf{R})$, where $\mathbf{R}$ is the residual variance-covariance matrix; $\mathbf{X}$ is a known incidence matrix relating elements of $\mathbf{b}$ to $\mathbf{y}$; $\mathbf{Z}$ is a known incidence matrix relating elements of $\mathbf{u}$ to $\mathbf{y}$. The covariance between $\mathbf{G}$ and $\mathbf{R}$ was assumed to be $\mathbf{0}$.

Table 1
Base population mean and breeding goal for selected traits.

Trait	Base population mean	Breeding foal
Average daily (ADG, g/day)	809	1000
Loin muscle area (LMA, cm^2)	35.5	38.0
Backfat thickness (BF, cm)	1.8	1.8

Let the set of restrictions on $\mathbf{u}$ be $\mathbf{C}'\mathbf{u} = \mathbf{0}$, where $\mathbf{C} = \mathbf{C}_0 \otimes \mathbf{J}$, $\mathbf{J}$ is an identity matrix with columns pertaining to no candidates for selection without constraints deleted (Satoh, 2004); $\mathbf{C}_0$ for relative desired changes (ADG: LMA: BF = 191: 2.5: 0) is as follows (Mallard, 1972; Itoh and Yamada, 1987):

$$\mathbf{C}_0' = \begin{bmatrix} 2.5 & -191 & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

The restricted BLUP of $\mathbf{u}$, $\hat{\mathbf{u}}$, is obtained by solving the restricted mixed model equations (Quaas and Henderson, 1976).

Let a sub-vector relating elements of the j^{th} animals of $\hat{\mathbf{u}}$ be $\hat{\mathbf{u}}_j$, then

$$\hat{\mathbf{u}}_j = \begin{bmatrix} \hat{u}_{ADG_j} \\ \hat{u}_{LMA_j} \\ \hat{u}_{BF_j} \end{bmatrix} = \tilde{u}_j \begin{bmatrix} 191 \\ 2.5 \\ 0 \end{bmatrix},$$

where $\tilde{u}_j$ is a scalar of the j^{th} animals. We can evaluate candidates for selection using the value of $\tilde{u}_j$.

2.3. Estimation of genetic parameters

Performance data for ADG, LMA, and BF, and body measurement data for BL, WH, HH, FW, CW, HW, CHD, CHG, and CNC were used for estimation of genetic parameters. Two animal models were compared as follows.

Model 1:

$$y_{ijklm} = Gen_{ij} + Sex_{ik} + Mon_{il} + ETW_i(X_m - \overline{X}) + a_{im} + e_{ijklm}$$

Model 2:

$$y_{ijklmn} = Gen_{ij} + Sex_{ik} + Mon_{il} + ETW_i(X_m - \overline{X}) + a_{im} + c_{in} + e_{ijklmn}$$

where y_{ijklmn} is observation for the i^{th} trait, Gen_{ij} is the fixed effect of the j^{th} generation (j = 1–9), Sex_{ik} is the fixed effect of the k^{th} sex (k = 1–2), Mon_{il} is the fixed effect of the l^{th} birth month of the pig (l = 1–3), ETW_i is a regression coefficient, X_m is body weight of the m^{th} pig at performance test, $\overline{X}$ is the average body weight at performance test, a_{im} is the random additive genetic effect, c_{in} is the random common litter effect of the n^{th} dam, and e_{ijklmn} is the random residual effect. The fixed effects and covariates in the models were determined according to a preliminary analysis of variance. Model selection was carried out by including significant fixed effects and covariate.

Variance-covariance components and their respective SE were estimated using multiple trait REML procedures (Groeneveld et al., 2010; VCE6). Standard errors of heritability and genetic correlation estimates were calculated using the VCE programs. The importance of common litter effect was assessed by likelihood-ratio test comparing maximum likelihood values. Ratio of likelihoods was used to compare models. The ratio $-2(\log\Lambda_1 - \Lambda_2)$ is asymptotically distributed as a chi-square with degrees of freedom equal to the difference in the number of parameters between the two models, where Λ is the value of the likelihood function for the model (Ferraz and Johnson, 1993).

3. Results and discussion

3.1. Descriptive statistics

Table 2 gives descriptive statistics for performance and body measurement traits in Duroc pigs. Coefficients of variation for ADG, LMA, and BF, which are selected traits, were similar to those in the previous literature on Duroc pigs (Li and Kennedy, 1994; Chen et al., 2002; Johnson et al., 2002; Suzuki et al., 2005a, 2005b; Hoque et al., 2008). Coefficients of variation for body measurement traits were small and the values ranged from 2.5% to 4.9%. Our results also agree with previous reports (Fukawa et al., 2001; Ishida et al., 2001).