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Genetic parameters for resilience related feed intake and feeding behaviours in Canadian Duroc pigs

D.N. Do[a], B. Kim[a], M. Jafarikia[a,b,c], D.Tulpan[a,c], D. Adewole[d], G. Plastow[e], B. Sullivan[b], J. Holl[f], and Y. Miar[a]

*[a]Dalhousie University, Truro, NS, Canada; [b]Canadian Centre for Swine Improvement, Ottawa, ON, Canada; [c]University of Guelph, Guelph, ON, Canada; [d]University of Saskatchewan, Saskatoon, SK, Canada; [e]University of Alberta, Edmonton, AB, Canada, [f]Pig Improvement Company, Hendersonville, TN, USA. *Corresponding author: duy.do@dal.ca/miar@dal.ca*

Introduction

Resilience is defined as the capacity to be minimally affected by disturbances and to rapidly return to normal performance (Knap and Doeschl-Wilson, 2020). In pigs, disturbances typically cause short-term drops or increase variability in feed intake and feeder use, so automatic feeder data records offer practical, non-invasive information to detect resilience-related patterns at scale. Identifying suitable phenotypes associated with resilience is an essential step in enhancing pig resilience via selective breeding (Berghof *et al*., 2019). Fluctuations in daily feed intake (DFI) and time spent in the feeder per day (TPD), measured using the root mean square error (RMSE) and quantile regression (QR), have been suggested as resilience indicators in several studies (Putz *et al*., 2019; Kavlak and Uimari, 2024). Resilience traits derived from feed intake and behaviour show low-to-moderate heritabilities, indicating that genetic improvement through selection is feasible (Putz *et al*., 2019; Gorssen *et al*., 2023). Studies report that some of these traits can be favourably associated with reduced sick days and show neutral or modest correlations with growth and feed efficiency, making them promising candidates for inclusion in breeding goals (Putz et al., 2019; Homma *et al*., 2020; Gorssen *et al*., 2023). Incorporating intake-based resilience traits into breeding programs can help identify pigs that maintain stable feeding patterns and performance in commercial environments. This study aimed to quantify resilience indicators derived from DFI and TPD and estimate their heritability and genetic correlations with growth and feed efficiency traits in Canadian Duroc pigs.

Materials & Methods

Animals and phenotypes. All pigs used in the current study were obtained from farms with no recorded disease events or significant herd-health concerns. Daily feed intake was measured using automatic feeding systems (FIRE® feeders, Osborne Industries Inc or IVOG® feeders, Hokofarm group) from 324 pens across 13 PIC farms in Quebec, Canada, between 2015 and 2022. During testing, these pigs were fed *ad libitum* using a commercial finisher diet formulated to meet the nutritional requirements for optimal growth and carcass quality. The average weight and age of the pigs at the start of the testing were 35.6±0.02 kg and 74.7±0.06 days, respectively. When pigs reached approximately 120 kg body weight, they were sent to a processing plant unless selected for breeding. The daily records were processed using the standardized procedures described by Casey *et al*. (2005). For the calculation of feed efficiency and feeding behaviours, only animals with a minimum of 60 consecutive days of feed intake records were kept. Additionally, only animals with start and end weights recorded within two days of their respective feed period start and end dates, and housed in pens with at least eight other pigs, were included. Resilience traits were derived using two distinct approaches to capture within-animal variability. First, individual

regressions of daily feed intake (DFI) and time per day (TPD) on age were performed, with the resulting root mean square errors ($RMSE_{DFI}$ and $RMSE_{TPD}$) serving as within-animal fluctuation indicators. Second, quantile regression-based traits (QR_{DFI} and QR_{TPD}) were calculated, representing the proportion of days an animal's negative residuals fell below the 5% quantile regression line for the population. Higher RMSE or higher QR values indicate lower resilience. After filtering, a total of 14,939 pigs (5,426 females and 9,513 males) with at least one phenotype were retained for feed efficiency modelling and feeding behaviour calculations. The variance components were estimated for each trait using the following univariate model (1):

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{Sc} + \mathbf{Wp} + \mathbf{e}, \quad (1)$$

in which **y** is the vector of phenotypic observations, **b** is the vector of fixed effects, **a** is the vector of random additive genetic effects, **c** is the vector of random common litter effects, **p** is the vector of random pen effects, and **e** is a vector of residual effects. The **X**, **Z**, **S**, and **W** are the incidence matrices associating the phenotypic observations to the fixed effects, random additive genetic effects, random common litter effects, and random pen effects, respectively. The pedigree comprising 24 generations and 116,221 individuals (1,134 sires and 5,634 dams) was used to construct the numerator relationship matrix. Phenotypic and genetic correlations among traits were estimated pairwise in bivariate models. All analyses used ASReml-R version 4.2 (Butler *et al*. 2008).

Results

Descriptive statistics, variance components and heritability. Descriptive statistics and heritability estimates for resilience traits are presented in Table 1. The estimated mean values of $RMSE_{DFI}$ and $RMSE_{TPD}$ were 0.49 kg and 12.14 min, respectively. Univariate analyses indicated that variability in resilience traits was significantly affected ($p < 0.05$) by both fixed effects (sex and herd–year–season) and random effects (additive genetic, pen, and common litter). The proportion of total phenotypic variance explained by pen and common litter were between 0.7% and 9.7% across traits. Heritability estimates (±SE) ranged from 0.04±0.01 for QR_{TPD} to 0.33±0.02 for $RMSE_{TPD}$.

Table 1: Descriptive statistics, variance components and estimated heritability for the traits.

Traits	Mean (SD)	Var by pen (%)[1]	Var by common litter (%)[1]	Heritability(±SE)
$RMSE_{DFI}$	0.49 (0.13)	2.4	3.6	0.09±0.01
$RMSE_{TPD}$	12.14(3.84)	0.7	9.7	0.33±0.02
QR_{DFI}	0.04(0.05)	9.5	3.6	0.05±0.01
QR_{TPD}	0.02(0.06)	3.1	4.1	0.04±0.01

[1]Percentage of phenotypic variance explained by pen and common litter effects.

Genetics correlations. Genetic correlations among resilience traits and between resilience and feed efficiency traits are presented in Table 2. Genetic correlations between $RMSE_{DFI}$ and $RMSE_{TPD}$, QR_{DFI}, and QR_{TPD} were 0.21, -0.53, and -0.29, respectively. Moderate positive genetic correlations were observed between $RMSE_{DFI}$ and feed efficiency traits, including DFI, FCR, and RFI (0.35, 0.52, and 0.50, respectively). In addition, $RMSE_{TPD}$ exhibited non-significant genetic correlations with DFI and RFI, but a weak negative correlation with FCR (-0.16). Genetic correlations of QR_{DFI} with RFI and FCR were -0.43 and -0.53, respectively, whereas the corresponding correlations between QR_{TPD} and these traits were low and positive (0.09 and 0.14, respectively)

Table 2: Genetic correlations (SE) between resilience with DFI and feed efficiency traits.

	$RMSE_{DFI}$	$RMSE_{TPD}$	QR_{DFI}	QR_{TPD}
$RMSE_{TPD}$	0.21(0.07)	-	-	-
QR_{DFI}	-0.53(0.11)	0.47(0.09)	-	-
QR_{TPD}	-0.29 (0.15)	0.21(0.03)	-0.30(0.05)	-
DFI	0.35(0.01)	-0.03(0.06)	-0.34(0.01)	-0.06(0.12)
RFI	0.50(0.06)	-0.03(0.06)	-0.43(0.01)	0.09(0.12)
FCR	0.52(0.06)	-0.16(0.06)	-0.53(0.01)	0.14(0.11)

Discussion

The estimated means and heritability for resilience traits in the present study were consistent with previously reported values. For example, the estimated means for $RMSE_{DFI}$ and $RMSE_{TPD}$ were close to the values of 0.42 kg and 11.1 min reported by Kavlak and Uimari (2024), or 0.47 kg and 13.19 min reported by Putz *et al*. (2019). Consistent with our findings, common litter was also shown to have a significant effect on resilience traits in Finnish pigs (Kavlak and Uimari, 2024). Furthermore, our heritability estimates align with those observed in previous studies (Putz *et al*., 2019; Homma *et al*., 2020; Gorssen *et al*., 2023). For instance, Putz *et al*. (2019) obtained moderate heritability estimates ranging from 0.15 for QR_{DFI} to 0.26 for $RMSE_{TPD}$, whereas Kavlak and Uimari (2024) reported low to moderate heritability estimates ranging from 0.07 for QR_{DFI} to 0.20 for $RMSE_{TPD}$.

Generally, weak to moderate genetic correlations were reported among resilience traits in pigs. The estimated genetic correlation between $RMSE_{DFI}$ and $RMSE_{TPD}$ (0.21) was close to the 0.26 reported by Kavlak and Uimari (2024), but slightly lower than the values reported by Putz *et al*. (2019) and Homma *et al*. (2021), who found moderate genetic correlations between $RMSE_{DFI}$ and $RMSE_{TPD}$ (0.43 and 0.47, respectively). The relatively weak correlation between $RMSE_{DFI}$ and $RMSE_{TPD}$ indicates that these traits may respond independently to selection.

Genetic correlations between resilience indicators and feed efficiency traits vary among studies. Putz *et al*. (2019) reported that $RMSE_{DFI}$ had non-significant genetic correlations with DFI (0.03), FCR (0.39), and RFI (-0.22), whereas Kavlak and Uimari (2024) reported positive and significant genetic correlations between $RMSE_{DFI}$ with both DFI (0.36) and FCR (0.41). In agreement with the results of the present study, both Putz *et al*. (2019) and Kavlak and Uimari (2024) reported negative genetic correlations between QR_{DFI} and FCR (-0.14 and -0.40, respectively). The variation among studies may be due to differences in breed, population structure, and experimental conditions. While Kavlak and Uimari (2024) and the present study used pigs from commercial settings without additional environmental challenges, Putz *et al*. (2019) and Homma *et al*. (2021) analyzed animals subjected to complex natural disease challenges.

Nevertheless, relationships with conventional efficiency traits have important implications for breeding decisions. $RMSE_{DFI}$ was genetically positively correlated with RFI, FCR, and DFI, indicating that selection for improved feed efficiency (lower RFI and FCR) is expected to indirectly reduce $RMSE_{DFI}$ and DFI. This may improve efficiency but also potentially narrow the range of intake responses available under nutritional or environmental stress. QR_{TPD} has recently been suggested by Kavlak and Uimari (2024) as a promising indicator due to its heritability, neutral genetic correlations with production traits (DFI, backfat, and average daily gain), and positive

association with health. Therefore, it is important to evaluate the relationships of this indicator with other production traits and health measures in the current population.

Conclusion

These findings highlight the potential value of including $RMSE_{DFI}$ or $RMSE_{TPD}$ in selection indices to simultaneously improve resilience and feed efficiency. Future work will focus on estimating genetic correlations between resilience traits and key growth and performance traits.

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