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Degree of connectedness among herds of three pig breeds in Korea

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ABSTRACT

The accuracy of comparing estimated breeding values (EBVs) among animals from different herds depends on the degree of connectedness among herds. In this study, the connectedness rating (CR) method was used to measure the degree of connectedness among pig herds in Korea. Data describing average daily gain (ADG) of three pig breeds (Duroc, Landrace and Yorkshire) from 2000 to 2015 of different herds were used. The results showed that most herds for each breed were well connected to one or a few other herds. All herds in all breeds had an average CR greater than zero. Generally, pig herds in Korea showed low-to-moderate average CR values (1.78–30.85%) with other herds. Among breeds, Duroc had the highest average CR, ranging from 9.79 to 31.07%. The average CR of Landrace ranged from 2.67 to 7.17%, while this value ranged from 1.78 to 28.15% for Yorkshire. Based on these results, national across-herd genetic evaluation in Korea is feasible. However, efforts are still needed to improve and establish the connectedness of few farms for which there was a low CR with other herds to enable more accurate EBV comparison. Furthermore, consistent sharing of boars should be maintained to sustain strong connections among herds.

Key words: Connectedness, Cross-herd genetic evaluation, Korea, Pigs

A national swine genetic evaluation system was established in Korea in 2015 under Golden Seed Project to achieve a single national consistent across herd genetic evaluation. The best linear unbiased predictor (BLUP) enables joint evaluation of animals from different herds and favors comparison of estimated breeding values (EBV) of animals in different herds. The accuracy of animal breeding values based on between farm comparisons is highly related to their genetic connectedness, with stronger genetic connectedness resulting in more accurate breeding value comparisons between herds and reduced bias (Kennedy and Trus 1993, Kuehn *et al.* 2007). Therefore, measurement of the degree of connectedness among herds is very important for effective across herd genetic evaluation.

Different methods for estimating connectedness have been developed, and commonly used methods include the connectedness index (Foulley *et al.* 1992), coefficient of determination (CD), which was first introduced by Laloë (1993) and further developed by Fouilloux *et al.* (2008), prediction error variance of all pair-wise EBV differences between animals in different management units (PEV) (Kennedy and Trus 1993), common sire percentage (Lewis *et al.* 1999) and connectedness rating (CR) (Mathur *et al.* 1998). The most appropriate measure of connectedness would be the PEV according to Kennedy and Trus (1993). Laloë *et al.* (1996) compared PEV with CI and CD and concluded that CD is the method of choice to measure connectedness because it combines genetic variability and PEV. However, PEV and CD are very difficult to apply to large populations with many management units because of the large quantity of computations involved (Mathur *et al.* 1998); therefore, an easier method is required. Soga *et al.* (2010) conducted a comparison of connectedness measures and suggested that CR was the most suitable measure because of its ease of computation.

In 2006, Swine Genetic Improvement Network Program was established in Korea that aims for exchange of favourable genetics among farms. Choi *et al.* (2014) and Cho *et al.* (2012) measured the connectedness among swine herds and birth years participated in semen exchange program. However, they only measured in Duroc pigs. To further improve the genetic merit of animals in national across-herd genetic evaluations in Korea, connectedness among herds must be considered. Therefore, this study was conducted to measure the degree of connectedness in three pig breeds among herds in Korea using the CR method.

MATERIALS AND METHODS

Data: Data from the national genetic evaluation program that represents the predominant pig breeding farms in Korea were evaluated in this study. Records regarding the average daily gain (ADG) between January 2000 and December 2015 of three main pig breeds (Duroc, Landrace and

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Table 1. Number of individuals, boars, herds and mean ADG with standard deviation by breed

Breed	Individuals	Boars	No. of herds	Mean ADG (g/day)
Duroc	39,451	21,500	4	651.81±66.42
Landrace	63,484	15,567	5	616.52±64.94
Yorkshire	165,043	26,016	8	601.77±63.89

ADG, average daily gain.

Yorkshire) from different herds were used to measure the connectedness among herds. The number of records and herds in each breed are presented in Table 1.

Analysis: The following mixed linear model was applied in single-trait analysis within each breed:

$$y = Xh + Za + e$$

where, y is the vector of observation on ADG, h is the vector of herd effects, a is the vector of random animal effects, e is the vector of random residual effects, and X and Z are matrices related to records to fixed (h) and random (a) effects, respectively.

It is assumed that the expectation (E) and the variance matrix of the random variables are:

$$E\begin{bmatrix}a\\e\end{bmatrix} = \begin{bmatrix}0\\0\end{bmatrix}, \qquad Var\begin{bmatrix}a\\e\end{bmatrix} = \begin{bmatrix}A\sigma_a^2 & 0\\0 & I\sigma_e^2\end{bmatrix}$$

where, σ_a^2 and σ_e^2 represent the additive genetic variance and residual variance, respectively, and A is the numerator relationship matrix. The mixed model equation used to solve for h, a and e given A, X, y and Z is:

$$\begin{bmatrix}X'X & X'Z\\Z'X & Z'Z + A^{-1}\alpha\end{bmatrix}\begin{bmatrix}\hat{b}\\\hat{a}\end{bmatrix} = \begin{bmatrix}X'y\\Z'y\end{bmatrix}$$

where, $\alpha = \sigma_e^2/\sigma_a^2$. The WOMBAT program (Meyer 2016) was used to construct the MME coefficient matrix. To compute the connectedness, only the coefficient matrix on the left hand side is needed.

Connectedness rating: The connectedness rating criterion by Mathur *et al.* (1998) was used to evaluate the connectedness between herds. The connectedness rating between two herds was defined as the correlation between the estimates of herd effects, i.e.

$$CR_{ij} = \frac{\mathrm{Cov}(\hat{h}_i, \hat{h}_j)}{\sqrt{Var(\hat{h}_i)\,Var(\hat{h}_j)}}$$

where, $Var(\hat{h}_i)$, $Var(\hat{h}_j)$, and $\mathrm{Cov}(\hat{h}_i, \hat{h}_j)$ are the variances and covariances of estimates of the respective herd effects obtained by solving the MME. Obtaining the variances and covariances requires the elements of the inverse of the coefficient matrix of the mixed model equation corresponding to the herd effects. In large data sets, it is very difficult to compute the inverse directly. Thus, Mathur *et al.* (1998) suggested the following procedure to compute the inverse elements for large data sets.

$$W'W(W'W)^{-1} = I$$

therefore,

$$W'W(W'W)_i^{-1} = I_i$$

where, $\boldsymbol{W'W}$ is the coefficient matrix of MME, I is an identity matrix, $(\boldsymbol{W'W})_i$ is a vector of corresponding to herd and I_i is a vector of the identity matrix corresponding to herd i. The vector $(\boldsymbol{W'W})^{-1}$ was obtained for one herd group at a time through iteration (1000 rounds). These vectors were combined and the block of inverse elements corresponding to the most recent herd groups was extracted. The inverse elements were the variances and covariances for the herd effects of interest. The program for calculating the CR using this method can be found at the website of the Canadian Center for Swine Improvement (http://www.ccsi.ca/connectedness/). The Animal Breeders Tool Kit (ABTK), a set of programs mainly used for genetic evaluations using BLUP approach, was also used in prior computations of connectedness.

RESULTS AND DISCUSSION

The minimum, maximum and average connectedness ratings for Duroc, Landrace and Yorkshire are shown in Tables 2, 3 and 4, respectively. The average CR for a herd was defined as the average of its connectedness ratings with all other herds in the program. The averages CR of a herd can be high because of the very high connectedness ratings among a few herds. However, according to Mathur *et al.* (1998), the average CR gives an indication of the accuracy of comparing EBVs from one herd to all others in the program. The Duroc population has 4 herds, while Landrace and Yorkshire has 5 and 8 herds, respectively.

All the herds in Duroc had an average CR greater than zero. The highest CR (63.80%) was observed between herd DF3 and DF4. Conversely, the lowest CR was found between herd DF1 and DF2 (6.98%). Herd DF3 had the highest average CR (31.07%) because it shares its boars with three other herds. Cho *et al.* (2012) also reported a very strong genetic connectedness in Duroc among farms in Korea. A high CR with another herd allows effective selection of animals from that herd, while a high average CR provides a broad basis for selection of superior animals

Table 2. Connectedness rating between herds of Duroc

Herd code	Connectedness rating (%)			Least connected herd	Most connected herd
	Average	Minimum	Maximum		
DF1	9.79	6.98	11.50	DF2	DF3
DF2	14.28	6.98	17.96	DF1	DF3
DF3	31.07	11.49	63.80	DF1	DF4
DF4	30.85	10.87	63.80	DF1	DF3

Table 3. Connectedness rating between herds of Landrace

Herd code	Connectedness rating (%)			Least connected herd	Most connected herd
	Average	Minimum	Maximum		
LF1	3.49	1.34	5.50	LF3	LF4
LF2	7.17	2.77	19.31	LF5	LF3
LF3	5.71	1.07	19.31	LF5	LF2
LF4	3.10	1.07	5.32	LF3	LF1
LF5	2.67	1.07	3.54	LF3	LF1

Table 4. Connectedness rating between herds of Yorkshire

Herd code	Connectedness rating (%)			Least connected herd	Most connected herd
	Average	Minimum	Maximum		
YF1	1.78	0.84	2.88	YF5	YF3
YF2	3.35	1.57	4.99	YF1	YF3
YF3	28.15	2.26	80.36	YF8	YF6
YF4	26.22	2.00	74.21	YF8	YF3
YF5	12.07	0.75	28.44	YF8	YF3
YF6	26.59	2.10	80.44	YF8	YF3
YF7	2.95	1.05	4.05	YF1	YF3
YF8	2.07	0.77	3.69	YF5	YF7

from all other herds in the program. In Landrace, the connectedness was generally weak compared to Duroc. The maximum CR was observed between herd LF2 and LF3, with a CR of 19.31%. The highest average CR of 7.17% was observed in LF2, which shares its genetics with all other herds. Among Yorkshire herds, the maximum CR was seen between herd YF3 and herd YF6 (80.44%). These two herds belong to one breeding company; hence, it is easy to exchange genetics. The highest average CR was observed in herd YF3 (28.15%). Moreover, this herd was the most connected with all other herds except for herd YF8. The lowest average CR was in herd YF1.

Mathur *et al.* (2002) recommended a minimum average CR of 3% for backfat and age at 100 kg to ensure a reasonably accurate comparison of EBVs between herds. Duroc herds satisfy this criterion, with an average CR ranging from 9.79% to 31.07%. Among the five herds in Landrace, only YF5 with 2.67% was below the recommended average CR. Three out of eight herds were below 3% for the Yorkshire breed. Sun *et al.* (2009) evaluated the connectedness between herds in China and concluded that cross-herd genetic evaluation is not practical at this time because of the low connectedness rating due to low use of artificial insemination (AI) in swine. In Korea, the semen exchanged program considerably improved the connectedness between herds. However, greater efforts are still needed to improve the level of connectedness of a few farms with other herds, especially for Landrace and Yorkshire pigs. The use of AI boars that have progeny in well-connected herds can accelerate the rate of increase in connectedness. Usually, about 15% of progeny from well-connected sires in a herd is sufficient to reach a minimum level of connectedness (Mathur 2005).

Most herds in Korea are well connected to one or a few other herds for each breed. Herds of all breeds have an average CR greater than zero. Moreover, there are very strong connections between herds of Duroc pigs. The average CR values among herds of all breeds ranged from 1.78 to 30.85%. Thus, national across-herd genetic evaluation in Korea is feasible. However, efforts are still needed to improve and establish the connectedness of a few farms, especially for Landrace and Yorkshire breeds, which have low CR values with other herds to enable more accurate EBV comparisons. Furthermore, continuous sharing of AI boars should be maintained to sustain the strong connection of herds.

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