Iberian pig selection in two different open-air production systems: GxE interactions for premium cuts percentage and intramuscular fat content

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ABSTRACT: Genotype by environment interaction (GxE) is a potential source of reduced efficiency in livestock genetic improvement programs. The objective of the current study consisted of checking the presence of GxE interactions for percentage of premium cuts (PC) and intramuscular fat content (IMF) in Iberian pigs fattened in two production environments: fenced open-air (C) and free-range (M) systems. Variance components and breeding values were estimated from records of 1,078 and 2,146 pigs fattened in C and M systems. Estimated heritability values (h^2) were higher in the environment with lower harshness (C): 0.68 vs 0.44 for PC and 0.53 vs 0.29 for IMF. Similar differences were observed using a more complex model, where data from each system are considered as different traits. Estimated genetic correlations between trait data recorded in each system (r^2= 0.42 for PC and 0.70 for IMF) also pointed out to a weak GxE interaction resulting in significant changes of animals breeding values between the two environments. The obtained results advise to consider these GxE interactions in the genetic evaluation of breeding programs based on records from these production systems.
Keywords: Iberian pig; open-air production system; GxE interaction

Introduction

Genotype by environment interaction occurs when performances of different genotypes are not equally affected by different environments (Falconer, 1952), and it is a potential source of reduced efficiency in selection programs because of the best genotypes in one environment are not necessary the best in the other one. Moreover, changes in genotype re-ranking due to GxE interaction are well documented in the genetic evaluation of farm animals. Montaldo (2001) reviewed different types of GxE interaction in livestock conditional to environmental differences as feeding level or test location (station or farm). GxE interaction due to fluctuations in feed quality has also been reported by Mulder (2007), and more recently Wallenbeck et al. (2009) examined GxE interaction in organic pig production using animals selected for high performance in a conventional production system.

Iberian pigs are produced in a range of low, medium and high input production systems, all of them focused on obtaining meat and dry-cured products characterized by their high sensorial quality. The traditional production system includes a finish-fattening period of about four months (November to March) known as *Montanera* (M) based on the ad libitum intake of acorns and pastures (López-Bote, 1998). However, most of the Iberian pigs are fattened with an intensive management using commercial feeds. A medium input production system has been recently developed, where the pigs use an enclosed territory being mainly fattened with commercial feeds besides of the grazing of seasonal grass or stubble. This second open-air system is named *Campo* (C).

The breeding goal of the public selection scheme managed by the Spanish Association of Iberian Pig Breeders includes the percentages on carcass weight of premium cuts and the content of intramuscular fat in loin (Silió, 2000). The breeding values are estimated from data recorded on pigs fattened in one of the two quoted environments. While the pigs move long distances in the *Montanera* system for a massive acorn intake, the conventional feeding of the *Campo* system is available within a lower fenced terrain. These remarkable differences in feeding and exercise between both production environments make advisable to study the possible GxE interaction for two traits: the percentage of premium cuts that represents more than a 50% of the carcass economic value and the intramuscular fat content as main meat quality trait.

Materials and Methods

Data. The analyzed data belongs to the official breeding scheme of the breed and were recorded from 3,224 castrated males born in 14 herds: 2,146 fattened in the M free-range system and 1,078 fattened in the C system. Only 21 out of 253 boars and 104 out of 1,275 sows have progenies fattened in each production system. Carcass weight (CW) and the percentage of premium cuts (PC, trimmed hams and shoulders) were recorded at diverse slaughter plants. Samples of longissimus dorsi were obtained from the caudal end of the muscle. The percentage of intramuscular fat (IMF) was measured in these samples by NIR (De Pedro, 1992). Table 1 summarizes the number of observations, means and coefficients of variations (CV) of the traits in each system. The age at slaughter showed a wide extent in the *Campo* system (from 11.9 to 26.3 months) because some animals had problems to reach the commercial weight.

Table 1. Number of observations (N), means and coefficients of variation (CV, %) of the recorded traits in both open-air production systems

Traits[1]	*Montanera*			*Campo*		
	N	Mean	CV	N	Mean	CV
SW, kg	4,348	160.9	10.1	1,818	165.1	8.7
CW, kg	4,348	128.5	11.2	1,818	130.5	9.9
PC, %	4,336	16.12	7.9	1,736	17.28	8.1
IMF, %	3,213	9.57	33.3	1,518	9.44	32.1

[1] SW, slaughter weight; CW, carcass weight; PC, premium cuts; IMF, intramuscular fat

Statistical analyses. Genetic parameters and animal breeding values were estimated using multivariate animal models, with two different procedures according to the treatment of GxE interaction, and the general form:

$$Y = X\beta + Zu + e$$

-PROC 1: A separate analysis was performed for each feeding system, where Y is the vector of data (PC and IMF) registered either in M or in C systems, β, u and e are vectors of systematic, additive genetic and residual effects respectively and X and Z are the incidences matrices. Systematic effects fitted in β were: slaughter batch (61 levels in M and 28 levels in C) and CW as covariate.

-PROC 2: A joint analysis was carried out using a model where the performances at each system were treated as different traits. The multitrait model is similar to PROC 1 but now Y is a vector of four elements (PC_M, PC_C, IMF_M and IMF_C).

Components of (co)variance and breeding values were respectively estimated using the VCE 6.0.2 (Kovac et al., 2008) and PEST 4.1 (Groeneveld et al., 1999) software.

The Pearson correlations coefficients between EBV were calculated for the 21 and 104 common boars and sows with offspring fattened in both systems, likewise the values of the Spearman rank correlations as a measure of the similarity of the order according to EBV.

Results and Discussion

Genetic parameters. The results related to the genetic parameters estimated with the different models are shown in Tables 2 and 3. The heritability values were clearly different in both systems, with values significantly larger in C (h^2= 0.66 and 0.50) that in M fattening system (h^2= 0.43 and 0.29). Moderate or high values of genetic correlations were estimated between both traits independently of the assumption of GxE interactions. Genetic correlations between the same traits recorded in the two systems were 0.42 for PC and 0.70 for IMF. These values significantly differ both from zero and from one. The estimated genetic correlations between IMF and PC were low and negative in both systems, although their standard errors prevent to differentiate them from zero.

Table 2. Heritabilities (diagonal) and genetic correlations (above diagonal) for percentage of premium cuts (PC) and intramuscular fat (IMF) estimated from separate analyses for each production system (PROC1). Standard errors between brackets.

	PC_M	PC_C	IMF_M	IMF_C
PC_M	0.43 (0.05)	0.42 (0.15)	-0.17 (0.11)	-0.53 (0.16)
PC_C		0.66 (0.07)	-0.10 (0.17)	-0.16 (0.09)
IMF_M			0.29 (0.05)	0.70 (0.18)
IMF_C				0.50 (0.08)

Table 3. Heritabilities (diagonal) and genetic correlations (above diagonal) for percentage of premium cuts (PC) and intramuscular fat (IMF) estimated by a joint analysis considering as different traits the performances at each production system (PROC 2). Standard errors between brackets.

	PC	IMF
Campo		
PC	0.68 (0.08)	-0.17 (0.13)
IMF		0.53 (0.09)
Montanera		
PC	0.44 (0.06)	-0.14 (0.12)
IMF		0.29 (0.06)

GxE interactions. The genetic correlation between records of the same trait obtained in different environments has been considered in animal breeding as the most useful criterion for assessing the relevance of GxE interaction. The expected value of this correlation would be equal to one in absence of GxE interaction. If this interaction occurs, the trait is partially influenced by different genes in each environment. Genetic correlations lower than 0.80 are expected to be important for reducing the genetic changes due to selection (Robertson, 1959). These interactions may cause over-predictions of the responses to selection if they are not taken into account in the breeding program (Dominik & Kinghorn, 2008).

Different types of GxE interactions have been described in farm animals (Montaldo, 2001). In absence of great environmental changes we expected a weak or moderate interaction in our study. The presence of GxE interaction has been mainly indicated by two complementary results. First, different h^2 values for PC and IMF content were obtained for each open-air system. Second, the estimated genetic correlations between records of the same trait from each system were clearly lower than one, providing an evidence of weak or moderate interaction. Although the small number of boars with offspring on both systems could partly explain these moderate correlations, the genetic connectedness between the two productive environments was supported by other relationships among the slaughtered pigs, because these animals proceeded from only 14 herds of small or moderate effective size, supplying animals to both feeding systems. The genetic relatedness between the reproducers of each herd would enable the presence of related genotypes in both systems.

GxE interactions are common in tropical areas and developing countries as results of the adaptation to diverse harsh environments or production systems (Montaldo, 2001). The pigs fattened under the *Montanera* system move longer distances than those of the *Campo* system. The first ones seek available acorns and pasture in a large land of variable orography, while the movement of the pigs fattened in the *Campo* system is restricted to a small open air enclosure with available water and commercial feed. It may explain the observed GxE interactions and the different heritabilities estimated in each system, with lower values for the analyzed traits in the *Montanera* system with larger sources of environmental variation. Similar results have been reported for other alternative production systems. Wallenbeck et al. (2009) found GxE interaction between organic and conventional pig production environments for growth rate and backfat thickness. Vallée (2007), analyzing growth traits in Creole beef cattle under tropical conditions, obtained lower heritabilities values in animals at pasture than those with intensive feeding regime.

Re-ranking of genetic merit. The importance of the observed GxE interaction can be also examined according to the Pearson and Spearman correlations between EBV and rank order (Figure 1). These correlations are very low with PROC 1 (below 0.6) and higher, but distinctly different from one, with PROC 2. Therefore important changes in ranking of EBVs of the reproducers of both genders may be observed between both production systems, and similar re-ranking should be expected for the genetic merit of the candidates to selection.

Weak GxE interactions justify the implementation of a joint evaluation considering as different traits recorded in each production system. With strong interactions, a distinct genetic evaluation for each system would be more suitable (Wallenbeck et al., 2009). Hence, the analysis with the current model applied in the public selection scheme, that fits the feeding system as a fixed effect, must be rejected because it assumes an identical expression of the traits in both systems. The implementation of a selection program without the IMF content on the selection goal must be taken with caution regarding the negative genetic correlations between quality and productive traits found in this study, that corroborates previous results (Fernández et al., 2004). An appropriate approach might be a selection index with PC weighted by the economic value and IMF treated as an optimum quality trait (Hovenier et al., 1993), with population average equal or next to the mean of the optimal range.

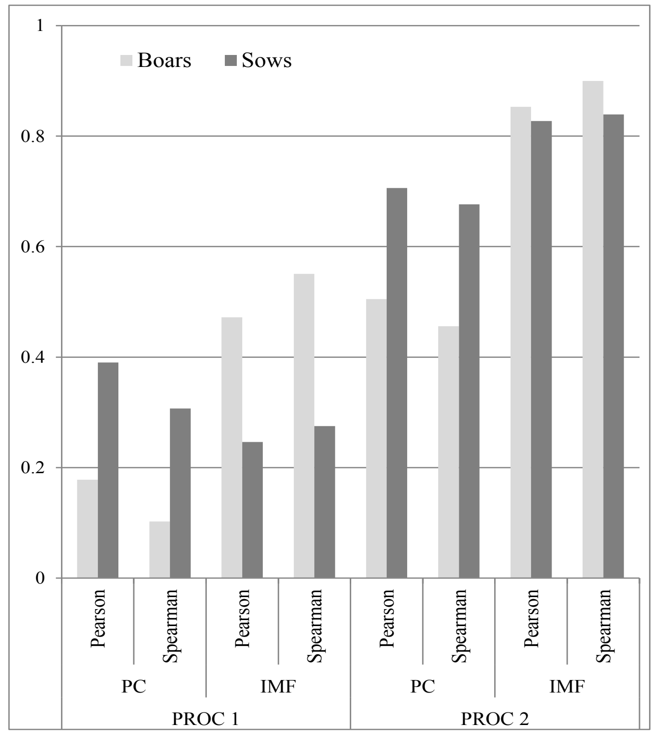

Figure 1. Correlation coefficients between EBVs (Pearson) and rank order (Spearman) calculated in *Montanera* and *Campo* of boars and sows with progeny fattened in the two feeding systems, using PROC 1 and 2

Conclusion

The results revealed GxE interaction between *Campo* and *Montanera* open-air production environments for PC and IMF, traits included in the objective of the public selection scheme of Iberian pigs. This interaction causes re-ranking of the genetic merit of boars and sows between both environments. A multivariate animal model should be the most appropriate to implement a new breeding program focused on open-air production systems, especially adequate for purebred Iberian pigs. Finally, the inclusion of IMF in the index selection would be advisable in order to avoid negative effects of selection for carcass performance.

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