Genotype by feed interaction in grower-finisher pigs fed different diets

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Summary

Global pig breeding programmes that have a central breeding goal, do not necessarily select the best pigs for specific local circumstances if genotype by environment interaction (GxE) is present. There is evidence for GxE for feed efficiency (FE) traits. While in the Americas, pigs are typically fed high-input diets based on corn and soybean meal (CS), in Western Europe it is common to feed pigs with diets based on wheat and barley (WB) with a high addition of protein rich co-products, e.g. from the milling and oil seeds industry. These two feeding scenarios provide a realistic set to verify the presence of a specific type of GxE due to feed, genotype by feed interaction (GxF). In the presence of GxF, selection for FE should consider the different diets of pigs. Residual energy intake (REI) appears as a good trait to measure FE, as utilization of energy in the diet is a foundational driver of FE. Genetic correlations between FE on different diets are largely unknown. Phenotypes of 2,230 three-way crossbred pigs offspring of F1 sows sired by a synthetic sire line and raised under commercial production conditions were available for this study. In total, 547 boars and 558 gilts were fed CS and 567 boars and 558 gilts were fed WB. Heritability estimates were higher in the group of pigs fed CS for the traits average daily energy intake (ADEI), lipid deposition (LD) and protein deposition (PD), and higher in the group of pigs fed WB for REI. Genetic correlations between the performances under both diets were 1.00, 0.62, 0.99 and 0.76 for ADEI, LD, PD and REI, respectively. GxF was found to compromise the lipid deposition (LD) and the residual energy intake (REI) of pigs on the different diets causing re-ranking of genotypes and heterogeneity of variance. Thus, the genetic progress realized under one diet is not fully carried over when pigs have to perform under the other diet. Selection for LD and REI should take place on the target diet.

Keywords: breeding program, correlated response, feed efficiency, genetic gain

Introduction

Utilization of energy in the diet is a foundational driver of FE (Patience et al., 2015). Residual energy intake is the difference between the observed and the expected energy intake animal would have based on the energy requirement for maintenance of live body weight (ME_m) and for lipid and protein accretion. There is evidence for genotype by environment interaction for feed efficiency (FE) traits (Knap and Wang, 2012). Composition of the diets can be a major source of variation between environments giving rise to genotype by feed interaction (GxF). In the presence of GxF, selection for FE should consider composition of pigs diets. We verified the presence of GxF for FE traits in three-way crossbred grower-finisher pigs fed different diets, and assessed and compared the expected response to direct selection under each diet and the expected correlated response for each diet to indirect selection under the other diet.

Material and methods

Dataset

Phenotypic records of 2,230 three-way crossbred pigs offspring of F1 sows (product of a Large White line crossed with one of either two Landrace lines) sired by a synthetic sire line were available for this study. The experiment was conducted in the facilities of Schothorst Feed Research B. V. (Lelystad, the Netherlands), under commercial production conditions. Pigs were put on test around 22 kg, and were taken off test and slaughtered on average 122 kg. The test period lasted around 106 days. The experimental design was a split-plot 2x2 with two diets, a corn and soybean meal (CS) versus a wheat and barley with a high addition of protein rich co-products (WB) based diet, and two sexes. In total, 547 boars and 558 gilts were fed CS and 567 boars and 558 gilts were fed WB. Pigs were put on test in 29 batches, each batch in one of the seven compartments of the farm available for the experiment. Each compartment had 8 pens with a maximum of 10 pigs per pen. Pedigree records were available for all animals, up to a maximum of 9 generations. A total of 3,991 animals were included in the pedigree file with 608 different sires and 1065 different dams.

Traits

All animals had their body weight (BW) recorded at start and end of the test period, and their back fat thickness measured on the carcass using the CGM probe (Sydel, France) at slaughter. Individual daily feed intake was recorded using IVOG®-stations (Insentec, the Netherlands).

Average daily energy intake (ADEI, MJ/d) was calculated as cumulative metabolizable energy intake during the test divided by the length of the test. Lipid deposition (LD, g/d) and protein deposition (PD, g/d) were estimated as the increment in lipid and protein mass content based on BW and back fat measurements (de Greef et al., 1994). Residual energy intake (REI, g/d) represents the efficiency of the energy metabolism, and was calculated as a linear function of ADEI, ME_m and the energy required for production (LD and PD) (Bergsma et al., 2013):

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Genetic parameters estimation and GxF analyses

For the GxF analyses, the trait measured on pigs fed the CS or WB diets was considered as different traits. Univariate analyses were performed to estimate the variance components and heritabilities of all traits, and genetic correlation estimates (r_g) were obtained using bivariate analyses. Values of r_g below 1 indicated presence of GxE (Falconer & Mackay, 1996). A linear mixed model implemented in ASReml (Gilmour et al., 2009) was used for the analyses as follows:

$$y = Xb + Za + Wl + Vg + e,$$

in which *y* is the vector of observations; *X*, *Z, W* and *V* are known incidence matrices; *b* is a vector of fixed effects of sex, cross, pen nested within compartment and BW; *a* is a vector of random additive genetic effects (breeding values), ; *l* is a vector of random non-genetic effects common to individuals born in the same litter,; *g* is a vector of random contemporary group effects (contemporary pen mates nested within batch mates),; and *e* is a vector of residuals,.

Response selection

The response (R) to direct selection under the target diet and the correlated response (CR) of a trait for one diet to indirect selection under the other diet were calculated as (Falconer & Mackay, 1996):

in which i is the intensity of selection (assumed to be 1 in this study), h is the accuracy of selecting under the target diet, and is the genetic standard deviation under the target diet.

in which is the genetic correlation between pigs performance under the two diets, is the genetic standard deviation under the target diet, is the genetic standard deviation under the other diet, and is the response to direct selection under the other diet.

Results and discussion

Differences between genetic variance and heritability estimates (Table 1) under the two diets will impact the response to selection (Table 2) that can be achieved by selecting on performance under the two diets. Under the CS, higher estimates were found for ADEI, LD and PD, therefore, the responses to selection that can be achieved under the CS will be higher than under the WB for these traits. Under the WB, higher estimates were found for REI, therefore, the response to selection that can be achieved under the WB will be higher than under the CS for this trait.

Table 1. Estimates of genetic variance, heritability (standard errors) and genetic correlations (standard errors) between the performances of pigs fed the different diets.

Traits					r_g
	CS	WB	CS	WB	CS x WB
ADEI	3978	1642	0.42 (0.12)	0.20 (0.11)	1.00 (0.21)
LD	597	311	0.23 (0.11)	0.16 (0.09)	0.62 (0.23)
PD	87	57	0.37 (0.11)	0.24 (0.11)	0.99 (0.14)
REI	2071	5322	0.09 (0.06)	0.25 (0.09)	0.76 (0.23)

= genetic variance, = heritability, CS = corn and soybean meal, WB = wheat, barley with high addition of by-products, ADEI = average daily energy intake, LD = lipid deposition, PD = protein deposition, REI = residual energy intake.

The values of r_g for the traits ADEI and PD were unity, showing that, according to this criterion, these traits behave as the same trait in both diets and that the genetic progress obtained for them under one diet will be fully expressed under the other diet. On the other hand, the moderate GxF found for LD and REI shows that these traits do not fully behave as the same trait when changing diets.

Table 2. Response to selection and correlated response to selection under the different diets.

Traits							
ADEI, MJ/d	96	42	0.4	64	63	0.7	1.5
LD, g/d	12	7.1	0.6	6.1	5.2	0.5	0.7
PD, g/d	5.7	3.7	0.7	4.5	4.6	0.8	1.2
REI, g/d	14	36	2.7	17	17	1.3	0.5

R = response to selection, *CR* = correlated response to selection, CS = corn and soybean meal, WBB = wheat, barley with high addition of by-products, ADEI = average daily energy intake, LD = lipid deposition, PD = protein deposition, REI = residual energy intake.

The CR that can be obtained for the performance under one diet by indirect selection under the other diet will depend on the and h in both diets and on the r_g between pigs performance under both diets. With r_g equal unity, direct selection will be beneficial when the and h will be higher under the target diet than under the other diet. This is the case for ADEI and PD. For LD, CR was lower than R in both situations. Thus, selecting under the target diet will lead to higher genetic progress for LD. For REI, and h were lower in the CS compared to the WB, and CR_{WB} was lower than R_{WB}. When the goal is lowering the REI of pigs under the WB, selection should be conducted under this diet.

Conclusions

GxF was found to compromise the lipid deposition (LD) and the residual energy intake (REI) of pigs on the different diets causing re-ranking of genotypes and heterogeneity of variance. Thus, the genetic progress realized under one diet is not fully carried over when pigs have to perform under the other diet. Selection for LD and REI should take place on the target diet.

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