Correlated Responses in Sow Feed Intake, Body Composition and Reproduction after Divergent Selection for Residual Feed Intake in the Growing Pig

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Introduction

Residual feed intake (RFI) represents the fraction of total feed intake which is not "explained" by maintenance and production requirements. Selection against RFI was suggested as a tool for increasing feed efficiency while having no correlated change in production traits (Kennedy *et al.* 1993). A divergent selection experiment on RFI is currently being carried out in the Large White breed; six generations of selection have been completed. Previous studies in mice and cattle (Hugues and Pitchford 2004; Meyer *et al.* 2008) found low to moderate correlations of RFI in growing animals with traits recorded in mature females. Moreover, the ability of sows selected for higher lean meat growth to sufficiently provide nutrients to piglets during lactation has been questioned. This study was performed to estimate genetic parameters and correlated responses for feed intake, body composition and reproduction traits of sows in lines selected divergently for RFI during growth.

Material and methods

Selection of the RFI lines. The selection criterion (index) was measured on group-housed Large White males fed *ad libitum* between 35 and 95 kg body weight (BW). It was defined as the difference between actual and predicted feed intakes, based on daily feed intake, average daily gain between 35 and 95 kg BW, and backfat thickness measured ultrasonically at 95 kg BW. Individual index were expressed as deviations from the average RFI of the contemporary pigs tested in the same batch, and transformed to have a 20-point standard deviation (SD) across lines. The low-RFI and the high-RFI lines were founded from the same Large White population, and developed simultaneously with 6 boars and 40 sows each per generation. Mass selection was applied in males only, selecting 6 males out of 96 candidates with a maximum of one pair of paternal half-sibs in order to limit the increase in inbreeding. No selection was applied to the females. In each generation, the same mating plan was retained for producing first-parity litters (P1) with fresh semen and second-parity litters (P2)

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with frozen semen as part of the selection experiment. A third parity was produced on a subset of sows using crossbred boars from different genetic types, as part of other experiments. The sows were then systematically culled and replaced by a daughter to produce the next generation. The full design of the selection experiment for RFI is described in detail by Gilbert *et al.* (2007).

Traits recorded. The data collected for this analysis cover the first seven generations of selected progeny, from G0 to G6, for 480 sows (1171 farrowing events) and 1065 candidates for selection. Sow body weight and backfat thickness were recorded before farrowing and after weaning. In order to control variation in fatness at the time of farrowing, feed supply was restricted during the two weeks before farrowing to fat sows. Feed intake of the sow was recorded volumetrically from farrowing to weaning. Food contained a minimum of 3300 Kcal of digestible energy per kg and 16 % crude protein. Sows were fed semi-restrictively on the basis of their appetite in the previous meal. Cross-fostering was applied when piglet or sow survival was at stake (5% of the piglets). Creep feeding was available from 21 days of age to weaning (28 days of age), but feed intake of the litter was not recorded.

The traits retained for the analysis were: daily feed intake of the sow from farrowing to 21 days after farrowing (DFI21) and to weaning (DFIw); body weight (BWf) and backfat thickness (BFTf) of the sow before farrowing; difference of body weight (D-BW) and backfat thickness (D-BFT) of the sow between weaning and farrowing; number of total born (TB), born alive (BA) and surviving biological piglets at weaning (NS) piglets; weight of the litter at birth (LWb), at 21 days (LW21) and at weaning (LWw); litter weight gain between birth and 21 days of age (D-LW21). Residual feed intake during lactation (SRFI) was defined as the amount of input (food and body reserves) used to support litter growth. To estimate the impact of creep feeding, two SRFI were computed with multiple regressions of DFI on the components of SRFI following the procedure used for the growing pig in Gilbert *et al.* (2007). The SRFI traits from farrowing to 21 days of age (SRFI21) and to weaning (SRFIw) were: SRFI21 = DFI21 + 0.020*D-BW + 0.012*D-BFT – 0.020*D-LW21 – 0.017*$BWw^{0.75}$; SRFIw = DFIw + 0.022*D-BW + 0.014*D-BFT – 0.022*D-LWw – 0.020*$BWw^{0.75}$; where $BWw^{0.75}$ is the metabolic BW of the sow at weaning.

Statistical analyses. Variance components were estimated using VCE6.0 (Neumaier and Groeneveld 1998) performing bivariate analyses of the index and target traits to account for the selection process. The pedigree comprised 4367 individuals, including G0 to G6 individuals and up to 9 generations of additional pedigree. Sow parity and a combination of herd and batch of farrowing were fixed effects; the age of the sow at farrowing was used as covariate. A direct animal effect and a permanent environmental effect of the sow were fitted. The interaction of line by generation was tested based on individual estimates of additive genetic values in order to assess responses to selection and differences in LSMEANS of the high-RFI line *vs* the low-RFI line for each generation.

Results and discussion

Genetic parameters. The heritability estimate of the index (Table 1) was very close to that found after four generations of selection (Gilbert *et al.* 2007). The heritability estimates for reproduction traits agree with literature values (Grandinson *et al.* 2005; Bergsma *et al.* 2008).

Genetic correlations with the index were not accurately estimated due to the limited number of records available. However, moderate genetic correlations with SRFI and DFI, as well as with body weight and fat loss during lactation, indicate that selection for reduced RFI in growing pigs reduces SRFI and DFI during lactation, and increases mobilization of body resources.

Table 1. Trait characteristics, estimates of heritability (h^2) and genetic correlation (r_A) with the index for the traits related to reproduction, along with direct and correlated responses to selection in G6 (RFI^+ - RFI^-)

Trait	Mean	Phenotypic SD	h^2 ±SE	r_A ±SE	RFI^+ - RFI^- (genetic SD units)
Index (points)	100	19	0.15 ±0.03	—	19.6*** (2.70)
SRFI21 (kg)	0	0.44	0.10 ±0.07	0.37 ±0.22	0.18*** (1.34)
SRFIw (kg)	0	0.48	0.16 ±0.07	0.35 ±0.20	0.17*** (0.88)
DFI21 (kg)	4.36	0.57	0.21 ±0.01	0.35 ±0.21	0.30*** (1.16)
DFIw (kg)	4.69	0.63	0.27 ±0.01	0.31 ±0.20	0.29*** (0.88)
BWf (kg)	262	20	0.15 ±0.06	0.12 ±0.21	4.48*** (0.51)
D-BW (kg)	34	15	0.14 ±0.02	-0.29 ±0.17	-5.35*** (-0.94)
BFTf (mm)	25.5	4.4	0.40 ±0.04	-0.06 ±0.19	0.21ns (0.07)
D-BFT (mm)	5.1	2.8	0.13 ±0.00	-0.36 ±0.20	-1.24*** (-1.22)
TB	12.4	3.7	0.17 ±0.01	0.01 ±0.19	-0.60*** (-0.40)
BA	11.6	3.5	0.16 ±0.05	-0.07 ±0.22	-0.66*** (-0.48)
NS	9.7	3.2	0.11 ±0.03	-0.06 ±0.20	-0.58*** (-0.55)
LWb (kg)	18.1	5.0	0.16 ±0.05	-0.07 ±0.15	-0.54*** (-0.27)
LW21 (kg)	63	12	0.09 ±0.05	-0.12 ±0.18	-1.83*** (-0.54)
D-LW21 (kg)	45	12	0.09 ±0.04	-0.14 ±0.26	-1.83*** (-0.54)

Responses to selection. The interaction between the generation and line was significant for all the traits, indicating significant responses to selection. Table 1 presents differences between lines in the sixth generation, when the index differed by 19.6 points, or 2.7 genetic SD of the trait. All the components of SRFI differed significantly between the lines in G6, from 0.54 to 1.22 genetic SD of the traits. During lactation, sows from the low-RFI line ate 290g less per day, lost more body weight (5.35 kg BW) and more backfat (1.24 mm) than sows from the high-RFI line. Moreover, their litters gained 1.83 kg more. Additionally, SRFI during lactation was 180g higher in the high-RFI line ($P<0.0001$), representing about 60% of the difference of DFI between the lines. These results are consistent with those previously reported in mice (Hugues and Pitchford 2004) but not with results reported in cattle (Meyer *et al.* 2008). Previous investigations of metabolism during growth in the RFI lines showed a reduced basal metabolism in the low-RFI pigs (Barea *et al.* 2010) and a shift in energy metabolism (low fat content, high muscle glycogen, Gilbert *et al.* 2007) that might persist during adult life and explain part of the difference in SRFI. Figure 1 shows that the major correlated responses for these traits occurred in the first generations of selection.

The lines differed significantly in terms of prolificacy and number of surviving piglets (about +0.60 piglet in the low-RFI line compared to the high-RFI line). Litter weight was larger in the low-RFI line at birth, and tended to be higher at weaning, despite smaller individual

piglet weights at birth (and not different at weaning – results not shown). At farrowing, sows from the low-RFI line tended to be leaner than sows from the high-RFI line, and they were lighter (-4.48 kg BW). This might be regarded as consequences of responses to selection for low RFI previously reported in growing pigs, with reduced growth rate and increased leanness at 110kg of body weight (Gilbert *et al.* 2007).

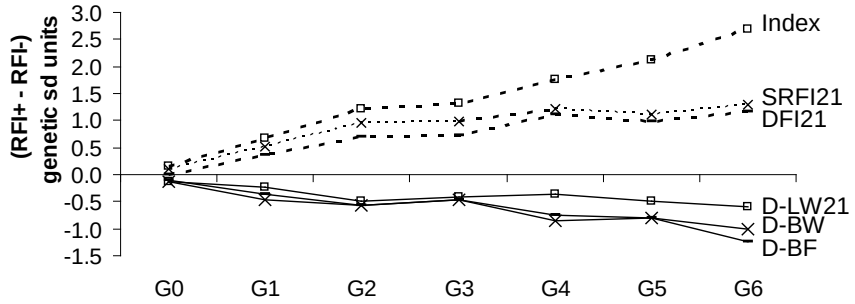

Figure 1: Responses to selection for the selection index, SRFI from farrowing to 21 days (SRFI21) and its components, in genetic SD units

Conclusion

Selection for RFI in growing pigs affected sow feed intake, body composition and litter performance. Although sows in the low-RFI line were lighter and leaner at farrowing and ate less during lactation, they also farrowed more piglets, which individually grew faster during lactation at the expense of body resources of the sow. Moreover, approximately 60% of the difference between lines in DFI during lactation was due to differences in SRFI during lactation, which is not due to differences for litter growth or body reserves mobilization.

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