Genetic analysis of individual piglet traits together with juvenile IGF-1 and performance traits

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Introduction

Heavier piglets are more likely to survive until weaning (see review by Le Dividich, 1999). Piglets with a larger birthweight have a higher pre-weaning growth rate (Bilkei and Biro, 1999) and better lifetime performance (Rydhmer et al., 1989). Overall, these phenotypic relationships indicate the importance of considering the role of piglet birth weights in breeding programs. In addition, further piglet weight traits may be recorded during lactation or at weaning. These traits provide further information about the combined potential of the piglet to grow and the mother to nurse a litter. As such piglet traits recorded after birth are of importance. However, cross-fostering is often practiced in nucleus herds and may limit the use of piglet traits recorded after birth.

There are two avenues to consider piglet weights in breeding programs. Firstly, piglet weight may be defined as a trait of the sow recording only the average piglet weight of the litter. Secondly, piglet birth weight may be defined as a trait of the piglet recording each individual piglet weight within a litter. The second definition, based on the individual piglet, is labour intensive to record which may explain why only a limited number of studies have only recently become available (Roehe, 1999; Högberg and Rydhmer, 2000; Kaufmann et al., 2000).

This paper presents genetic parameters for individual piglet traits and estimates of genetic correlations between piglet traits and juvenile insulin-like growth factor-1, growth, backfat traits and muscle depth. The second paper in this workshop presents estimates of genetic parameters for litter traits of the sow.

Description of individual piglet data

Approximately 25000 piglets were weighed individually at birth and at 14 days over a two-year period in three maternal lines at Bunge Meat Industries (BMI). Individual piglet weight at birth (IPWB) was recorded within 12 hours after birth for every piglet within a litter, and included stillbirths and piglets that had already been crushed by their mother. Piglets were raised in commercial conditions and cross-fostering was practiced. The second piglet weight trait was recorded at exactly 14 days after birth (IPW14). This trait was only recorded for piglets, that stayed with their mothers or were cross-fostered to a sow that was part of the project. These two weight traits were then used to derive the average growth of the piglet from birth to 14 days (ADG14). The final analyses included 24329 records for IPWB, 13640 records for IPW14 and 13611 records for ADG14. The data set included 2297 litters from 180 sires and 1797 sows.

This individual piglet data was then combined with the overall herd recording system to retrieve information on juvenile insulin-like growth factor-1 (IGF-1), lifetime growth rate, backfat traits and muscle depth. Blood samples were taken within the first week after weaning to record concentrations of juvenile IGF-1, when piglets were 25 to 35 days of age. Concentration of juvenile IGF-1 levels was measured using a commercially available ELISA according to the manufacturer's instructions (DSL Inc, Webster, Texas, USA). Animals were then raised in commercial conditions at BMI. The weight of the animal and carcase traits were recorded at 154±3.8 days of age.

Factors influencing piglet traits

The fixed effects influencing piglet traits and performance traits were analysed using the SAS procedure GLM (SAS, 1988). The week of farrowing, sex of the animal, line and parity of the sow and their interaction were significant for each piglet trait (Table 1). The two piglet traits recorded at 14 days of age were also influenced by whether or not a piglet had been cross-fostered. These fixed effect models explained nine to 15 per cent of the total variation for piglet traits.

Table 1. Number of records (N), coefficient of determination (R^2) and fixed effects for piglet traits

Trait	N	R^2	Week	Line	Parity	Line by Parity	Sex	Fostered
IPWB	24 329	0.09	***	***	***	***	***	
IPW14	13 640	0.15	***	***	***	***	***	***
ADG14	13 611	0.12	***	*	***	***	**	***

Abbreviations:

IPWB: Individual piglet weight at birth
IPW14: Individual piglet weight at 14 days of age
ADG14 Piglet growth rate from birth to 14 days of age

Cross-fostering reduces piglet growth

Both piglet traits recorded at 14 days of age were influenced by whether or not a piglet had been cross-fostered. Both traits are partly influenced by the piglet's birthweight. Analyses showed that piglets with low birth weights were more likely to have been cross-fostered than heavier piglets. An additional analysis showed that cross-fostering was still a significant factor influencing piglet growth rate after adjusting piglet growth for piglet weight at birth. Cross-fostering reduced growth rate until 14 days of age for piglets born in first, second and third parity litters by 14, 17 and 33 grams, respectively (Figure 1).

Factors influencing IGF-1 and performance traits

The fixed effects for juvenile IGF-1 included the day of bleeding, the sex and line of the animal and age at bleeding as a linear covariable (Table 2). These fixed effects explained 19 per cent of the total variation. Including the piglet's weight at 14 days of age in the model explained an additional two per cent of the total variation. However, estimates of genetic parameters were not altered significantly and given that individual piglet weight at 14 days of age is not routinely recorded in nucleus herds, this effect was excluded from the model.

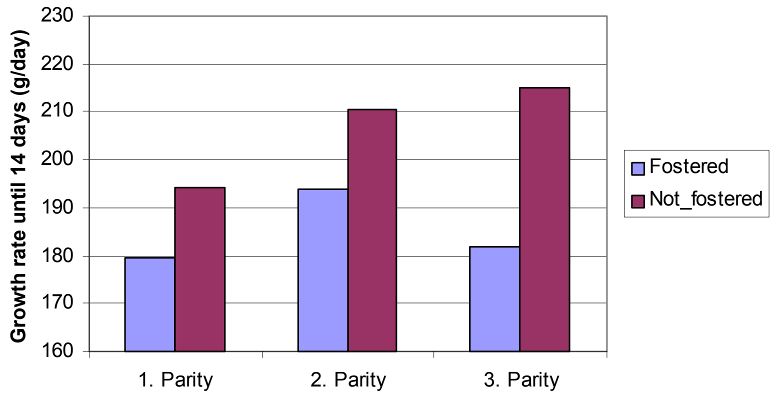

Figure 1. The effect of cross-fostering on piglet growth rate for piglets being born in first, second and third parity litters

The month of recording, line and sex of the animal were included in the models for growth rate and backfat. In addition, the weight of the animal at recording was fitted as a linear covariable for backfat and muscle depth traits. The coefficients of determination were 0.14 for growth rate, 0.31 for backfat at the P2 site and slightly lower (0.26) for backfat above the tail and eye muscle depth.

Table 2. Number of records (N), coefficient of determination (R^2) and fixed effects for IGF-1 and performance traits

Trait	N	R^2	Day of bleeding	Line	Sex	Age at bleeding 1)	
IGF-1	9990	0.19	***	***	***	**	
			Month of testing	Line	Sex	Parity of sow	Weight at testing 1)
ADG	4420	0.14	***	***	***	***	
BFP2	4484	0.31	***	*	***		***
BFT	4476	0.26	***	***	***		***
EMD	2163	0.26	***	***	***		***

1) fitted as linear covariable

Abbreviations:

IGF-1	Juvenile insulin-like growth factor 1
ADG	Lifetime growth rate
BFP2	Backfat at P2 site
BFT	Backfat above the tail
EMD	Eye muscle depth at P2 site

Variance components for piglet traits

Genetic parameters were estimated using ASREML (Gilmour et al., 1999). Piglet weights are influenced by the piglet's own genetic potential for growth (heritability estimate), its litter environment (litter effect) and the maternal genetic effect (maternal heritability).

The reliable estimation of these three random effects requires a data structure covering multiple generations, repeated litter records per sow and several piglet records within a litter. The structure of this data set may have limited the reliable simultaneous estimation of all three random effects. A number of different random effect models were therefore employed to define the best random effect model. These models have been described in detail in Hermesch et al. (2001) and only the model including all three random effects is presented here for each piglet trait (Table 3).

Heritability estimates were low for the three piglet traits, indicating that the piglet's own genetic potential for growth is not expressed at this early age. Estimates of maternal genetic effects were 0.20 for IPWB, 0.13 for IPW14 and 0.09 for ADG14. Litter effect estimates ranged from 0.20 to 0.23 for these three traits. These estimates agree with results presented by Roehe (1999) and Kaufmann et al. (2000) who analysed data sets that included data from multiple generations.

Table 3. Heritabilities (h^2), litter effects (c^2) and maternal genetic effects (m^2) and phenotypic variance (σ^2_p) for individual piglet traits.

Trait*	Unit	h^2	c^2	m^2	σ^2_p
IPWB	kg	0.03	0.20	0.20	0.116
IPW14	kg	0.04	0.22	0.13	0.752
ADG14	gr/day	0.04	0.23	0.09	2895

*for abbreviations see Table 1.; range of standard errors: 0.01 to 0.02

Genetic correlations between piglet traits

The two individual piglet weight traits were genetically different traits (Table 4). The maternal genetic correlation was slightly higher (0.73) in comparison to the estimate of the genetic correlation (0.52). Piglet growth rate is a linear combination of both weight measurements which explains the high correlations with piglet weight at 14 days of age and the lower correlations with individual piglet birth weight.

Table 4. Genetic (r_g), litter effect (r_c), maternal genetic (r_m), environmental (r_e) and phenotypic correlations (r_p) (with standard errors) between piglet traits

Trait1	Trait 2	r_g	r_c	r_m	r_e	r_p
IPWB*	IPW14	0.52 (0.24)	0.66 (0.03)	0.73 (0.05)	0.64 (0.01)	0.65 (0.01)
IPWB	ADG14	0.23 (0.26)	0.38 (0.06)	0.36 (0.09)	0.36 (0.01)	0.36 (0.01)
IPW14	ADG14	0.97 (0.03)	0.96 (0.004)	0.90 (0.02)	0.96(0.001)	0.95 (0.001)

* for abbreviations see Table 1

Variance components for juvenile IGF-1 and performance traits

Maternal genetics effects were not significant for juvenile IGF-1, lifetime growth rate backfat traits and muscle depth. Heritabilities and litter effect estimates for these three traits are presented in Table 5. The heritability estimate of 0.24 for IGF-1 corresponds well with previous studies, which have been summarised by Kim Bunter in her review presented in these workshop notes. Growth rate and backfat have frequently been analysed before. Both, heritability and litter effect estimates agree with previous estimates (UNE17P, UNE20P) showing that each data set represents a random sample of the overall population. Overall, heritability estimates of 0.22 for growth rate and 0.41 for backfat are similar to the average literature values presented by Clutter and Brascamp (1998). The heritability of 0.28 for muscle depth shows that it is possible to improve this trait through breeding programs.

Table 5. Heritabilities (h^2) and litter effects (c^2) along with standard errors (se) and phenotypic variance (σ^2_p) for juvenile IGF-1, growth rate and backfat

Trait*	**Unit**	**h^2**	**se**	**c^2**	**se**	**σ^2_p**
IGF-1	ng/mL	0.24	(0.03)	0.13	(0.01)	629
ADG	g/day	0.22	(0.04)	0.12	(0.02)	3474
BFP2	mm	0.41	(0.05)	0.06	(0.01)	4.4
BFT	mm	0.40	(0.05)	0.05	(0.02)	7.95
EMD	mm	0.28	(0.07)	0.03	(0.03)	22.6

*for abbreviations see Table 2.

Genetic correlations

Estimates of genetic correlations between individual piglet traits and the traits currently used in breeding programs; juvenile IGF-1, growth rate and backfat are required to evaluate the usefulness of individual piglet traits for genetic improvement. In addition to this aspect, genetic correlations between individual piglet traits and juvenile IGF-1 may provide clues as to why juvenile IGF-1, in contrast to IGF-1 concentrations measured in finisher pigs, is an informative selection criterion for improving feed conversion ratio and lean meat growth. Estimates for these traits are shown in Table 6.

Individual piglet birthweight had a negative genetic correlation of –0.33 with juvenile IGF-1. In contrast, genetic correlations between juvenile IGF-1 and piglet traits available at 14 days of age piglet weight were lowly positive. Estimates were 0.10 for individual piglet weight at 14 days of age and 0.22 for piglet growth rate until 14 days of age. A similar pattern of genetic correlations was observed between both backfat traits and the three piglet traits. At birth, individual piglet weight had negative genetic correlations of -0.48 and -0.63 with both backfat traits in comparison to a slightly positive genetic correlation with piglet growth rate.

Genetic correlations between individual piglet birthweight and backfat measurements indirectly support results by Herpin et al. (1993) who showed that selection for higher lean meat growth resulted in heavier piglets at birth. A higher piglet birthweight in turn is genetically related to a lower level of juvenile IGF-1 which has a positive genetic correlation with both backfat measurements. Estimates of genetic correlations were 0.46 for backfat at P2 and 0.57 for backfat above the tail. Overall, these estimates indirectly support downward selection for juvenile IGF-1 in order to increase lean meat growth.
Piglet growth rate until 14 days of age had lowly positive genetic correlations with juvenile IGF-1 and backfat measurements. Growth in young piglets is largely determined by the sow's milk volume and composition. The sow’s milk is rich in fat and low in protein promoting fat deposition rather than lean meat deposition. High rates of fat deposition may explain the shift to a lowly positive genetic correlation between juvenile IGF-1 concentrations and piglet growth rate until 14 days. The negative genetic correlation of –0.50 between piglet growth rate until 14 days of age and eye muscle depth indirectly supports the assumption of high fat deposition during the early days in a piglets

life since muscle depth had negative genetic correlations with both backfat measurements.

Table 6. Genetic (r_g) and phenotypic correlations (r_p) between individual piglet traits and juvenile IGF-1, growth rate, backfat and muscle depth traits.

Trait*		IGF1	ADG	BFP2	BFT	EMD
IPWB	r_g	**-0.32** (0.20)	0.49 (0.16)	**-0.48** (0.18)	**-0.63** (0.16)	-0.06 (0.26)
	r_p	0.04	0.41	-0.14	-0.20	-0.06
IPW14	r_g	**0.10** (0.20)	0.55 (0.18)	**-0.02** (0.21)	**-0.07** (0.21)	-0.49 (0.26)
	r_p	0.09	0.32	-0.06	-0.08	-0.05
ADG14	r_g	**0.22** (0.18)	0.37 (0.19)	**0.15** (0.19)	**0.11** (0.20)	-0.50 (0.25)
	r_p	0.10	0.26	-0.03	-0.04	-0.04
IGF1	r_g		0.12 (0.12)	**0.46** (0.08)	**0.57** (0.08)	-0.21 (0.14)
	r_p		0.11	0.24	0.08	0.02
ADG	r_g			0.07 (0.12)	0.03 (0.12)	-0.32 (0.16)
	r_p			0.02	-0.04	-0.11
BFP2	r_g				0.89 (0.03)	-0.36 (0.14)
	r_p				0.70	-0.10
BFT	r_g					-0.31 (0.15)
	r_p					-0.07

* Abbreviations see Tables 1 and 2.

Individual piglet weight traits – what is their use for genetic improvement?

Individual piglet traits do not have an economic value themselves. (Survival of piglets is discussed in the second paper). Therefore, these traits would only be useful by providing extra information for economically important traits. Individual piglet weight at birth had moderate genetic correlations with lifetime growth rate and backfat. However, individual piglet weights had low heritabilities and are therefore only of limited use in breeding programs. Given that this trait is labour intensive to record it is recommended not to record individual piglet traits for genetic improvement programs.

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