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Effects of Selection on the Efficiency and Variability of Sow Reproduction and Maternal Abilities

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Introduction

Selection has been implemented in pig populations for several decades. Initially, the breeding goal was to increase growth, feed efficiency and carcass lean content. Since the early 1990's, litter size has become a major component of the breeding goal in French Large White (LW) and Landrace (LR) breeds, leading to large genetic gains on litter size (Tribout *et al*., 2003; Guéry *et al*., 2009). This improvement may unfortunately be accompanied by detrimental effects on other economically important traits. For instance, an increase in piglet mortality was shown in French LW by Tribout *et al*. (2003) and Canario *et al*. (2007). Animal robustness, defined as the ability to maintain a good level of performance over a wide range of environments (Knap, 2005) could also unfavourably be affected by selection (Phocas *et al*., 2014).

The adverse effects of selection are difficult to detect, as only a limited number of traits are routinely recorded in breeding programmes. The use of frozen semen is a simple and powerful way of measuring genetic trends for a large number of traits (Smith, 1977). This approach has been used in French LW population to estimate genetic trends from 1977 to 1998. Tribout *et al*. (2010) estimated genetic trends for growth and carcass traits. Preliminary results for reproduction traits were presented by Tribout *et al*. (2003).

The objective of this study is to analyse the full set of data of the experiment described by Tribout *et al*. (2003; 2010) and investigate the effects of selection on the variability of sow and piglet performance as a potential indicator of their robustness.

Materials and Methods

Animals

French large white sows were inseminated in the INRA GENESI experimental unit (17700 Surgères) with either stored frozen semen from 17 LW boars born in 1977 (G7) or with semen from 23 LW boars born in 1998 (G8). Thirty and 33 litters, respectively, were produced from G7 and G8 boars. After weaning, half of piglets from each litter and sex were transferred to the INRA experimental herd of Bourges (18520 Avord). Fifteen males from each group, as well as 74 G7 and 89 G8 females were chosen at random to produce a second generation by within group matings. Pigs from this second generation will be noted as D7 and D8.

D7 and D8 sows were kept for 6 litters. They were managed under a batch farrowing system, with three weeks intervals between successive batches. They were inseminated twice when oestrus was detected. Farrowing was induced with prostaglandin on the 113th day of gestation. The day of farrowing, total number born (TNB), number of stillbirths (SB) and number born alive (NBA) were recorded for each litter. All piglets born were individually weighed within 24 hours after farrowing.

In order to disentangle sow and litter effects on piglet growth, cross fostering was used on a large scale in order to let sows from each group nurse 50% of their own piglets and 50% piglets from the other genetic group, and litter sizes were standardised (D7 and D8 sows nursed 7 and 12

piglets/litter, respectively). Sows were fed ad-libitum from about d 5 of lactation and their daily feed consumption was recorded. Conversely, no creep feed was distributed to piglets before 21 days (d) of age in order to accurately estimate sow milk production. The piglets were weaned at four weeks of age (28 d on average). Piglets were individually weighed at 21 d of age and at weaning.

Sow traits analysed included TNB, NBA, SB, litter weight at birth (LWB), litter growth weight from birth to 21 d of age (LGR21d), weaning to oestrus interval (WOI), total (SWL_t) and net (SWL_n) sow weight loss during lactation - SWL_t = sow weight at farrowing (SWF) minus sow weight at weaning (SWW) ; SWL_n = SWF – SWW - (0.3 + 1.329 LWB) (Dourmad *et al*., 1997). Sow longevity (LONG) was computed as lifespan from birth to last weaning. Piglet traits included individual weight at birth (IWB) and at 21 d of age (IW21d), average daily gain from birth to 21 d of age (ADG21d) and to from birth to weaning (ADGW).

Statistical analysis

Traits were analysed using mixed linear models with the SAS Mixed procedure. The model for sow traits included genetic group, herd, farrowing batch within herd and parity as fixed effects, sow and litter sire as random effects. The model for piglet traits included the same effects as for sow traits, plus litter genetic group and a sex effect. Interactions between fixed effects were tested in preliminary analyses and kept in final models when significant.

The homogeneity of residual variances across genetic groups (D7 vs D8) was also tested using SAS MIXED procedure. When variances significantly differed, the final analyses were performed using a model accounting for different variances in D7 and D8 groups. The estimated annual genetic trend (ΔGa) and its standard error (SE) for each trait were computed using the following formulae (Smith, 1977): $\Delta Ga = (2*(\mu_{D8} - \mu_{D7}))/21 \pm (2*SE_{D8-D7})/21$, Where μ_{D8} and μ_{D7} are estimates of genetic group effects and SE_{D8-D7} the standard error of the contrast between D8 and D7.

Results and Discussion

The annual genetic trend and group least squares means for sow traits are given in Table 1. D8 sows had larger litter sizes and weights than D7 sows; gains from 1977 to 1998 were 2.48 ± 0.96 and 1.89 ± 0.95 piglets for TNB and NBA, respectively, and 4.78 ± 1.21 kg for LWB. The lower genetic trend for NBA as compared to TNB resulted from an increase in the number of stillbirths (SB: +0.68 piglet, $p<0.09$). The percentage of stillbirths was not globally different between groups, but was higher for D8 in the latter parities.

Table 1. Least squares means and annual genetic trends for sow performance

Trait[1]	Observation		Mean performance		Δ Ga ± SE	Pr > | t | for H0 : ΔGa = 0
	D7	D8	D7	D8		
TNB	252	283	11.59 ± 0,52	12.83 ± 0.45	0.12 ± 0.06	0.009
NBA	252	283	10.40 ± 0.52	11.29 ± 0.44	0.09 ± 0.06	0.050
SB	252	283	1.18 ± 0.24	1.52 ± 0.21	0.03 ± 0.03	0.09
LWB (kg)	220	237	15.81 ± 0.70	18.20 ± 0.62	0.22 ± 0.08	0.0007
LGR21d (kg)	185	196	2.64 ± 0.09	2.41 ± 0.10	-0.02 ± 0.13	0.06
SWL_t (kg)	228	251	32.7 ± 2.1	38.3 ± 2.2	0.52 ± 0.28	0.04
SWL_n (kg)	228	251	15.2 ± 2.6	14.2 ± 2.4	-0.09 ± 0.33	0.7
WOI (day)	107	109	5.6 ± 0.3	4.4 ± 0.3	-0.10 ± 0.04	0.001
LONG (day)	252	283	354 ± 34.5	261 ± 39.3	-8.8 ± 3.87	0.02

[1]TNB = total number born; NBA = number born alive; SB = number of stillbirths; LWB = litter weight at birth; LGR21d: litter growth rate from 0 to 21 days of age; SWL_t = total sow weight loss from farrowing to weaning; SWL_n = net sow weight loss from farrowing to weaning (see text); WOI = weaning to oestrus interval; LONG = sow longevity.

The large increase in LWB (>1 kg every five years - P<0.0007) indicated an improved ability of D8 sows to provide nutrients to their foetuses during gestation, i.e. an improved "uterine capacity". Conversely, with a similar number of piglets nursed, LGR21d was lower in D8 as compared to D7 sows, which indicates a decreased milk production of D8 as compared to D7 sows. SWL_t was higher in D8 as compared to D7 sows (Table 1), corresponding to a genetic trend of 11.2 kg after 21 years of selection. Yet, as shown by the lack of group difference for SWL_n, this higher loss was entirely due to the increase in piglet and embryonic tissue weights. The interval from weaning to first oestrus was more than one day shorter in D8 sows (p<0.01), as compared to D7 sows.

Table 2 shows the effects of both sow and piglet genetic group on individual piglet weights and growth rate. Though born in larger litters, D8 piglets tended to be heavier at birth than D7 piglets (+66g; P=0.07). Least squares for IWB_{cf} clearly showed that the heaviest piglets were cross fostered in both groups, with a difference of 48 g and 74 g over non cross fostered piglets in D7 and D8 groups, respectively). Conversely, the average IWB_{cf} of piglets nursed by D7 and D8 sows were similar (respectively, 1482 g and 1469 g).

In accordance with results on LGR21d, piglets nursed by D7 sows had a larger ADG21d than those nursed by D8 sows (+12 g/d), with a larger difference for D7 as compared to D8 piglets (+17 g/d vs +7 g/d). As a result, piglets nursed by D7 sows were heavier at 21d than those raised by D8 sows (+0.36 kg and +0.18 kg, respectively, for D7 and D8 piglets). Globally, the effect of piglet genetic group was limited (D8-D7 equals +2 g/d and -0.12 kg, respectively, for ADG21d and IW21d). Adjusting the 2 traits for IWB has a limited impact on the results. Estimated genetic trends were non significant at the piglet level and negative (estimates of ΔGa for $ADG21d_{aj}$ and $IW21d_{aj}$ were -1.3 g/d and -14 g, respectively).

Table 2. Least squares means for piglet performance

traits [1]	Mean performance				P-value
Sows	D7		D8		
Piglets	D7	D8	D7	D8	
IWB (g)	1441 ± 33			1507 ± 28	0.07
IWBcf (g) *	1416 ± 30 [a]	1548 ± 31 [c]	1464 + 29 [ab]	1474 + 25 [b]	0.0001
ADG21d (g/d)	235 ± 6 [a]	232 ± 7 [a]	218 ± 6 [b]	225 ± 5 [ab]	0.01
$ADG21d_{aj}$ (g/d)	237 ± 6 [a]	231 ± 7 [a]	219 ± 6 [b]	222 ± 5 [ab]	0.02
IW21d (g) *	6.40 ± 0.16 [a]	6.43 ± 0.16 [a]	6.04 ± 0.14 [b]	6.25 ± 0.13 [ab]	0.06
$IW21d_{aj}$ (g) *	6.49 ± 0.16 [a]	6.38 ± 0.16 [a]	6.11 ± 0.14 [b]	6.15 ± 0.13 [ab]	0.08

[1] IWB = piglet individual weight at birth; IWBcf = individual weight at birth after cross fostering; IW21d = individual weight at 21 days old; ADG21d = average daily gain until 21 days old; * different superscript in the same line is significant different.

Within group residual standard deviations (RSD) for each trait are given in table 3. RSD was significantly larger in D8 than in D7 sows for NBA and WOI, as well as for piglet traits. The increased RSD of D sow indicates that their performance is more variable during their productive life. This result is in agreement with Johnson et al. (1999), who also showed an increased variability of performance at birth as a result of selection for litter size. This higher variability can be considered as detrimental for both physiological and management reasons. This heterogeneity may partly explain the significantly higher within-litter variability of D8 piglets at birth. A higher variability is also observed for ADG21d and IW21d, but it is more difficult to interpret, as piglets were not randomly allocated to their nurse genetic group.

Conclusion

This study shows that selection in French LW breed has resulted in strong improvement of sow performance during gestation. Globally, modern sows are much more productive at birth then

old sows. However, selection has not been accompanied by an improvement in sow milking performance, has had detrimental effects on sow longevity and has resulted in more heterogeneous performances during their productive life. These trends could be interpreted as a decrease in sow robustness. Taking into account these traits in future breeding goals in sow dam lines might be desirable.

Table 3. Standard deviation of residual variance of sow traits

Trait [1]	Standard deviation		P-value
	D7 [2]	D8 [2]	
TNB (piglet)	2.32 ± 0.16	2.65 ± 0.15	0.13
NBA (piglet)	2.14 ± 0.15	2.60 ± 0.14	0.03
LW21d (kg)	7.68 ± 0.70	8.62 ± 0.65	0.32
WOI (day)	1.79 ± 0.28	1.09 ± 0.29	0.0001
IWB (g)	279 ± 10	306 ± 9	0.002
IW21d (g)	1037 ± 58	1158 ± 51	0.003
ADG21d (g)	43 ± 2	49 ± 2	0.001
	D7 [3]	D8 [3]	
IWB (g)	269 ± 10	305 ± 9	0.0001
IW21d (g)	1016 ± 58	1136 ± 51	0.003
ADG21d (g)	44 ± 2	49 ± 2	0.002

[1] TNB = total number born; NBA = number born alive; WOI = weaning to first oestrus interval; IW21d = individual weight at 21 days of age; ADG21d = average daily gain until 21 days of age; [2] genetic group of nurse sows; [3] genetic group of piglets.

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