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Genetic analyses of new feed efficiency traits in Norsvin Landrace

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Summary

The main objective of this paper is to establish more detailed feed efficiency measures in Norsvin Landrace to genetically improve feed efficiency without negative consequences for other important traits. The data was provided by Topigs Norsvin, and consisted of records from the boar testing station and the Norwegian litter recording system. Individual feed intake and body weight were recorded daily and all boars were computed tomography-scanned to determine their deposition of lean meat and fat at the end of test. In addition, data from purebred Norsvin Landrace sows was available. Two new measures, lean meat- and fat efficiency, were investigated for boars. Total feed intake in the test period was analysed in a multivariate animal model, where fat and lean meat deposition were included as random regression covariates. Significant genetic variation in these new efficiency measurements was detected. Genetic correlations between lean meat efficiency, fat efficiency and sow traits (stayability, body condition score at weaning, total number of piglets born and total litter weight at three weeks of age) were estimated. Two significant genetic correlations were found, between fat efficiency and stayability (0.21 ± 0.11) and between fat efficiency and total litter weight at three weeks (0.21 ± 0.10). There were no significant genetic correlations between lean meat efficiency and the sow traits. These results suggest that selection for fat efficiency could give poorer stayability in sows and reduce the litter weights at three weeks. It might be possible to select for improved lean meat efficiency without a negative effect on important sow traits.

Keywords: feed efficiency, body condition score, genetic parameter, maternal line

Introduction

Feed efficiency is an important trait in pig breeding due to global issues such as human population growth, climate changes and economics in pork production. Therefore, an efficient pig is important to defend the use of resources such as cereals, which could be human food, for pork production. In addition, Shirali *et al.* (2012) showed that selection for residual feed intake led to reduced nitrogen excretion in pigs. As climate changes and increased human population leads to an increased scarcity of resources, the prices of agricultural commodities will increase. Feed is the major cost in pork production, which makes feed efficiency an important trait for the profit of the farmer (Niemi *et al.*, 2010). The Norsvin Landrace is highly feed efficient and has a high ability to mobilize energy from body reserves (Kolstad & Vangen, 1996). This is a result of systematic selection for reduced feed intake per kg growth (FCR), increased lean meat growth and reduced back fat. However, it has been shown that such selection may result in reduced appetite in lactating sows and unfortunate consequences on profitable traits in piglet production in maternal lines (Kerr & Cameron, 1996). The aim of this paper was to investigate new measures for feed efficiency, namely lean meat efficiency

(LME) and fat efficiency (FE), and perform genetic analyses of these new traits together with other economically important traits in Norsvin Landrace.

Materials and methods

Feed intake on boars originated from nucleus herds in Norway and was recorded at Topigs Norsvin's (TN) boar test station. At the station test, individual feed intake and weight were measured daily on all boars entering the test by a FIRE-station (FIRE; Osborne Industries Inc., Osborne, KS, USA) in each pen of 12 pigs. In total, 8,161 Norsvin Landrace boars were included in the data set. At the end of the test, all boars were scanned by computed tomography (CT) and through image analysis of CT- data, each boar got a phenotype for amount of lean meat and fat on the carcass. Martinsen *et al.* (2015) provided a more detailed description of the data. The sow traits included in the analysis were body condition score after weaning of first litter (BCSw), stayability up to insemination of second litter (STAY), total number of piglets born in first litter (TNB) and total litter weight of first litter at three weeks (TLW). These traits were recorded in the Norwegian litter recording system (Ingris). Sows younger than 250 days, older than 730 days when farrowing, and sows weaning piglets older than 70 days were discarded. Only sows with at least two piglets in the litter were included in the analysis. Further details about the dataset are given in Martinsen *et al.* (2016).

The traits were analysed in a multivariate animal model, and estimation of variance components and genetic correlations were performed in a multivariate analysis using the DMU software package (Madsen & Jensen, 2013).

Total feed intake in the test period. The trait and model are defined in Martinsen *et al.* (2015). For the trait, total feed consumption in the test period (FI) in boars at the test station, the following model was used for analysis:

$$\mathbf{FI_{ijknoqrs} = HY_i + BM_j + ST_k + SEC_n + \beta_{lm} \times LMEAT_o + \beta_{fat} \times FAT_q + \beta_{amw} \times AMW_r + a_s + pen_t + a_{p_s} \times lmeat_o + a_{f_s} \times fat_q + e_{ijknoqrs}} \quad (1)$$

The fixed effects included in the model were birth herd-year (HY), birth month (BM), scanning time (ST) and section in the test station (SEC). The boars' phenotypes for carcass lean meat (LMEAT), carcass fat (FAT) and accumulated metabolic body weight (AMW) were included as fixed regression covariates. As measures of feed efficiency, random regressions on amount of lean meat (lmeat) and fat (fat) ($\mathbf{a}_{p_s}$ and $\mathbf{a}_{f_s}$, respectively) were included in the model as in Martinsen *et al.* (2015). These represented the new efficiency measures, LME and FE. The animal's genetic effect ($\mathbf{a}_s$) (later referred to as RFI) and pen (pen) were included as random effects.

Body condition score at weaning was analysed in the following model, which is used by TN for their routinely genetic evaluation of the trait:

$$\mathbf{BCSw_{ijklmnopq} = M\_LNO_i + HY_j + SEA_k + BRYEAR_l + WEAN_m + \beta \times AGEM_n + \beta \times AGEW_o + animal_p + litter_q + e_{ijklmnopq}} \quad (2)$$

The fixed effects in the model was dam's litter number (M_LNO), birth herd-year (HY), season (SEA), breed of the litter-year of the record (BRYEAR) and number of weaned piglets (WEAN). Sow's age at farrowing (AGEM) and litter's age at weaning (AGEW) were both included as fixed regression covariates in the model. The animal's breeding value (animal), litter's identity (litter) and the residual (e) were included as random effects.

Stayability up to second insemination was analysed as:

$$\mathbf{STAY_{ijklmno} = M\_LNO_i + BY_j + HYS_k + BR_l + \beta \times AGEM_m + animal_n + litter_o + e_{ijklmno}} \quad (3)$$

In the model, M_LNO, birth year (BY), herd-year-season of the record (HYS) and breed of the litter (BR) were treated as fixed effects in addition to the effects described in model 2.

Total number of piglets born and litter weight at three weeks was analyzed by the model below, which is identical to TN's model in the routine genetic evaluation of this trait:

$$\mathbf{TNB = M\_LNO_i + HY_j + SEA_k + BRYEAR_l + \beta \times AGEM_m + litter_n + animal_o + e_{ijklmno}} \quad (4)$$

The effects in model 4 were the same as for BCSw (model 2), without the fixed regression covariate of AGEW. For TLW, the model was the same as model 4 but also included the fixed effect of number of piglets weighed in the litter.

Results

Estimates of variance components and heritabilities for all traits are presented in Table 1 and all genetic variances were significantly larger than zero. Low to moderate heritabilities were found for TNB, STAY, BCSw, and TLW (0.07, 0.10, 0.13 and 0.16). The estimated heritability for RFI was remarkably high (0.59).

The estimated genetic correlations from the multivariate analysis are presented in Table 1. Overall, the genetic correlations were relatively low and mostly non-significant. Significant correlations were found between RFI and both efficiency measures (LME and FE), suggesting that animals with a high overall feed intake had a lower efficiency (higher feed intake per kg deposited lean meat and fat). The correlations between RFI and the sow traits were positive, but low, and mostly not significantly different from zero. Still, a positive and significant correlation was found between RFI and BCSw. The genetic correlations between FE and sow traits were positive (unfavourable), but low. Significant positive correlations were found between FE and STAY (0.21 ± 0.11) and FE and TLW (0.21 ± 0.10). These results suggested that selection for fat efficient pigs might result in poorer STAY and reduce TLW. The genetic correlations found between LME and the sow traits were low and non-significant.

Discussion

The aim of this paper was to model new feed efficiency measurements that could be used for further genetic improvement of feed efficiency in pig breeding. Innovative ways of modelling feed efficiency in pigs are desired due to concerns regarding a biological limit for improving feed efficiency through changes in body composition (increased lean growth and reduced back fat) and lower feed conversion ratio (FCR). Genetic variation was found in both feed efficiency traits, and few unfavourable genetic correlations to important sow productivity traits were found. For the piglet production traits (TNB and TLW), the heritabilities agreed with TN's genetic parameters and were slightly lower than those found by Aasmundstad *et al.* (2014). Heritability for BCSw was in accordance with earlier results found in Norsvin Landrace, analysed as linear traits in multitrait animal models (Lundgren *et al.,* 2014). In the current study, STAY was defined as a binary trait with success (1) if the sow was inseminated again after first litter and a failure (0) if the sow was culled after first litter. The estimated heritability of the current study was 0.10, which was slightly lower than estimates obtained by Aasmundstad *et al.* (2014) for the same breed (0.13). Stayability is a complex trait, influenced by several traits such as reproduction and lameness and environmental factors such as herd management and temperature. A low heritability might be expected, as the genetic component of STAY may be difficult to depict due to the trait being influenced by the sow's biology and the farmer's management decisions. The heritability of FI found in this project was high compared to earlier estimates. Lower heritability estimates have been found for total feed consumption in performance test by earlier studies (Kerr & Cameron, 1996). The model used for analysis of total feed intake in the test period in this study was very complex. In pork production, daily feed intake is a conflict of interest between the fattening pig production and the piglet production. Low feed intake and high growth are important for the fattening pig producers, while higher appetite and daily feed intake in sows are crucial to produce large litters and to avoid high weight loss (Eissen *et al.*, 2003). No information was available on the sows' feed intake in this study, but the sows' production (TLW) and BCSw could give an indication whether their feed intake was sufficient during lactation. To look at the genetic relationships between the new feed efficiency traits and these sow traits would be beneficial to see if potential selection for these new traits would have a deleterious effect on these important sow traits. Few significant genetic correlations were found and selection for LME could be possible without affecting the sow traits, whereas selection for improved FE could give poorer STAY and TLW. The results are in accordance with an earlier study investigating the relationship between boar feed efficiency and important sow production traits (Gilbert *et al.*, 2012). Still, it has been shown that lines selected for low residual feed intake had a higher number of piglets born and heavier litters compared to unselected lines (Young *et al.*, 2010). This was explained by a higher ability to mobilize body reserves during lactation in animals selected for low residual feed intake to compensate for the reduced feed intake to support the increased piglet production.

Table 1 Genetic correlations (r_g) and heritabilies (h^2) for residual feed intake (RFI), lean meat efficiency (LME), fat efficiency (FE), body condition score at weaning (BCSw), stayability from first to second parity (STAY), total litter weight at three weeks (TLW) and total number of born piglets (TNB).

	Trait	RFI	LME	FE	BCSw	STAY	TLW	TNB
	LME	0.25(0.07)						
	FE	0.71(0.05)	-0.19(0.12)					
r_g	BCSw	0.16(0.07)	-0.03(0.13)	0.13(0.11)				
	STAY	0.12(0.07)	-0.14(0.12)	0.21(0.11)				
	TLW	0.09(0.06)	-0.16(0.11)	0.21(0.10)				
	TNB	0.03(0.08)	0.14(0.14)	-0.05(0.12)				
h^2	-	0.59	-	-	0.13	0.10	0.16	0.07

Conclusion

Genetic variation existed in both LME and FE. No significant genetic correlations were found between LME and important sow traits, whereas low but significant genetic correlations where found between FE and STAY and FE and TLW.

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