A Random Regression Analysis of Sow Lactation Feed Intake and the Effect of Temperature on Intake

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Introduction

Lactation feed intake (LFI) has only recently been considered as a possible selection criterion to assist in tackling the issue of sow longevity. It has been postulated that adequate LFI is needed to maintain sow body condition and development and to provide for suckling offspring. Hermesch and Jones (2007) showed that, on average, primiparous sows eating <3.5kg/day during lactation were significantly less likely to farrow in their second parity. Previously LFI, defined as the daily intake averaged across the lactation, has been shown to be a heritable trait (Bergsma *et al*. 2008; Hermesch, 2007). However it has also been demonstrated that the heritability estimates differ across the lactation curve (Hermesch, 2007). Considering that LFI is recorded over time and the trait is measured repeatedly on the sow, a more appropriate model to estimate the parameters could be random regression (Schaeffer, 2004). While random regression analyses have been utilized to examine finisher feed intake in pigs (Schnyder *et al*. 2001; Huisman and van Arendonk 2004) no published work using random regression is available for LFI. To add further complexity to both LFI and longevity, the effect of heat stress has been implicated as a cause for a reduction in LFI and also longevity. This study sought to firstly understand the temporal component of LFI in the random regression context and then further quantify the effect of temperature on LFI.

Material and Methods

Data collection. Primiparous sows from two nucleus lines (Primegro Genetics™) were recorded for daily LFI over their whole lactation. Lines were of Large White and Landrace origin and housed within the same environment. For this study, data from 2,030 sows recorded over 28 days of lactation were used, resulting in 51,542 intake records. Although some sows lactated longer than 28 days, for these analyses the lactation data post four weeks were discarded as animals lactating to four weeks were considered to have completed a full lactation. At day one of lactation there were 2,030 records, reducing to 1,424 records by day 28. These sows were progeny of 216 sires, and the full pedigree contained 60,870 animals from 705 sires. The primiparous sows were fed “to appetite” with increased presentation of feed when the sow had finished all feed from the previous meal (feeding three times daily).

Temperature data were collected and validated by the Australian Bureau of Meteorology from a weather station approximately 16km from the piggery. Data consisted of multiple measurements including air temperature and relative humidity, recorded hourly. Heat and temperature-humidity indices were also generated from these data based on Fitzgerald *et al*.

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(2008). A comparison of alternative measures in preliminary analyses demonstrated that the 24 hour average of the raw air temperature (TMP) on a given day of lactation explained similar variation in the raw data when compared to the average of thermal indices. For simplicity of interpretation, only TMP was used for random regression models.

Statistical Analysis. In previous work using these data (Bunter *et al*. 2008; 2009) the best model for analysis of lactation average daily intake (LADI) contained the fixed effects of year/month of farrowing (FYM) and sow line (L), along with the significant covariates of number of piglets on the first day of lactation (ND1) and lactation length (LACL). For the random regression analysis, with the exception of LACL, the same model terms were used. The regression trajectory variable was day of lactation (DAY). Interactions between DAY and the other fixed effects were tested for significance ($P<0.05$). For the random regression, Legendre polynomials (LEG) were preferred to the general orthogonal polynomials for analysis. Legendre polynomials have been used previously for similar analysis. Model selection (to decide the order of polynomial to fit) was based on Akaike's Information Criterion for the random terms, and F-tests for the fixed effects. After testing zero to fifth order polynomials, a second order polynomial (quadratic) was deemed sufficient for DAY and a first order term (linear) was sufficient for TMP for both fixed and random terms. The full models used in this study are shown in Table 1. For random effects, two terms were fitted. Identity (ID) accommodated covariances between repeated observations within sow, whereas the additive genetic effect was estimated using an animal model. A homogenous residual variance was assumed. It was not possible to achieve convergence using a model that fitted random terms for both DAY and TMP simultaneously.

Table 1: Models used in the random regression (see text for abbreviations)

	Fixed Effects	Random Terms
Model 1	FYM + L + ND1 + LEG(DAY,2nd) + L×LEG(DAY,2nd)	LEG(DAY,2nd).ID + LEG(DAY,2nd).Animal
Model 2	FYM + L + ND1 + LEG(DAY,2nd) + L×LEG(DAY,2nd) + LEG(TMP,1st)	LEG(TMP,1st).ID + LEG(TMP,1st).Animal

Results and Discussion

With respect to the random effects in model 1, 21% of the phenotypic variation (σ^2_p: 4.03) in daily intake was due to the permanent environment of the sow; only 5% was additive genetic in origin. For model 2 (σ^2_p: 4.04) these proportions were 8% and 15% respectively, highlighting the higher proportion of error variance associated with model 2.

When LFI data was analyzed individually by day (results not presented) there was limited genetic variation (heritability estimates ranged from approximately 0.00 to 0.08). The averages of estimated phenotypic (σ^2_p) and genetic (σ^2_a) variances were 3.75 and 0.10. These heritability estimates are well below those published for average LFI from the same data (Bunter *et al*. 2008), demonstrating the importance of repeated records for lactation feed intake. Results from the random regression analysis (Model 1) showed that the trajectory of LFI heritability estimates along the lactation curve were reasonably constant and slightly positive after day 9 (Figure 1a). The averages across the trajectory were: heritability 0.04;

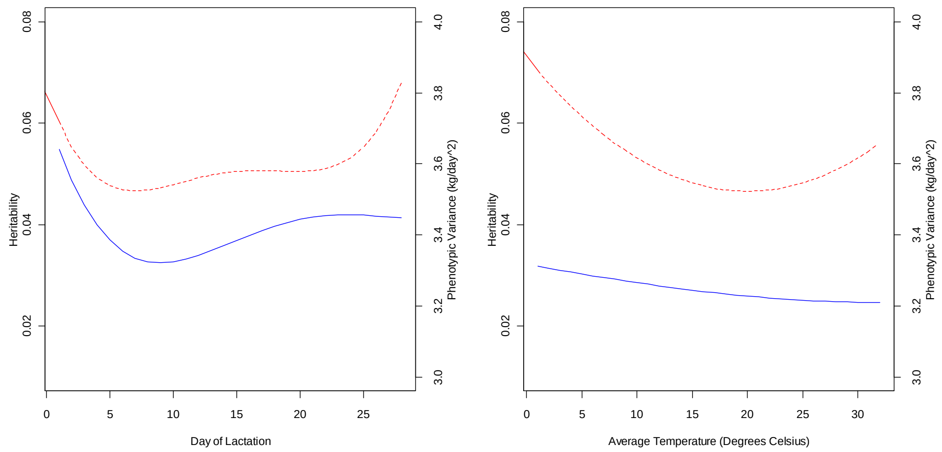
σ^2_p: 3.60 with residual variance (σ^2_e): 2.99. These results are consistent with the heritability estimated for average LFI, which can be derived approximately from these results as $\sigma^2_a/(\sigma^2_a + \sigma^2_{ID} + (\sigma^2_e/n))$, where n is the number of days averaged. Over 28 days, the heritability for average LFI would be around 0.17, derived as (0.14/(0.14+0.46+0.21)), in line with previous estimates (Bunter *et al*. 2008).

When Figure 1a is compared to results of Schnyder *et al*. (2001), who analyzed finisher feed intake data in Large White pigs, their heritability estimates also gradually increased over time, although the average estimate of the heritability by day was higher (~0.16). However, compared to results in this study, their curve depicting heritability estimates was smoother at the beginning of the test period. A pig entering into feed intake testing at finishing is not subjected to a major stress event with variable outcomes, such as parturition, which affects lactation intake in the following few days. For example, LFI was more heritable in medicated (i.e. stressed) pigs (Bunter *et al*. 2009) which may support increased heritability at the beginning of lactation when sow medication typically occurs. A comparison between these studies also suggests that a parameter estimate based on a single record is uninformative for LFI, but was much more informative for feed intake of a finisher, with respect to genetic potential for intake. The slight increase in the phenotypic variation at the end of lactation is potentially due to increasing variability amongst sows to maintain or further increase intake.

The effect of temperature on lactation feed intake parameters is shown in Figure 1b. Increased phenotypic variation amongst sows in LFI was evident outside the pigs thermal neutral zone of approximately 12-22^{o}C (Black *et al*, 1993), highlighting the effect of temperature stress. Including temperature terms in the model for analysis marginally decreased the heritability estimates for feed intake. Heritability also declined with increasing temperature; there was more genetic variation at temperatures lower than 12^{o}C (average ~0.12 kg/day^2) compared to temperatures above 22^{o}C average ~0.09 kg/day^2). Maintaining LFI under high temperatures is the goal in the farrowing house, and this was where genetic variation in LFI was at its lowest.

In terms of systematic effects, FYM, L, and ND1 accounted for 10.1% of the overall trait variation, the fixed effect of LEG(DAY,2nd) accounted for an additional 7.7%, while the interaction between L and LEG(DAY,2nd) accounted for another 0.0002%. The linear effect of TMP added to model 1 explained only 1% more variation. However, since FYM captures seasonal effects, TMP and FYM are quite confounded. In total, model 1 explained 18% of the overall trait variation, and model 2: 19%. Averaged across the two lines, solutions for linear and quadratic terms were 0.07 kg/day and -0.002 (kg/day)^2, demonstrating a curvilinear increase in intake with day of lactation. Sows must adapt to a larger intake over time and also respond to the increasing demand of suckling piglets and other environmental stimuli. The linear solution for TMP indicated that for every 1^{o}C increase in average temperature during lactation the sow would eat 0.04 kg less per day. Although this is most likely true at higher temperatures, one would expect that intake would be relatively stable in the thermal neutral (comfort) zone and only increase linearly again at lower temperatures, due to higher maintenance requirements. However, a more complex model for the intake curve was not significant in these studies and this pattern was also not observed in the raw data.

Figures 1a&b: Heritability (solid line) and phenotypic variance (dashed line) for daily intake under model 1 and model 2 (accounting for temperature).



Conclusions

Although feed intake increased during lactation, parameter estimates were similar across the lactation curve. Since the heritability of LFI based on a single record is very low, it is necessary to use repeated records to define a trait with adequate heritability and variability for selection applications. The most appropriate interval to record might vary with the intended application. Phenotypic variation for LFI of sows subjected to temperatures outside their thermal neutral zone increased; heritability and genetic variation were highest at low temperatures. Temperature may therefore affect heritability estimates for LFI, and potential for genetically increasing lactation intake appears lowest at high ambient temperatures.

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