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SURVIVAL ANALYSIS FOR THE PRODUCTIVE LIFE OF COMMERCIAL SOWS

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SUMMARY

A stratified survival analysis was compared with a non-stratified model to identify significant factors affecting the productive life of commercial sows and to estimate the heritability for sow productive life. Data for 3,074 sows were used for the survival analysis under a Cox model. The stratified model identified factors associated with sow survival that were not statistically significant in an unstratified model. High average daily feed intake and low feed conversion ratio reduced the risk of culling (solutions: -0.35 and 0.30) prior to herd entry; higher total born in parity one reduced the culling risk (solution: -0.032) prior to the second farrowing; and higher fat levels, treated as a time dependent covariable, reduced risk (solution: -0.026) of culling throughout the sows lifetime. After accounting for risk factors, the heritability for survival on the underlying scale was 0.04±0.001, demonstrating that the heritable component for survival is not solely attributable to the influences of other heritable traits.

INTRODUCTION

Declining sow longevity is an important issue for global pig production. However, while there have been several studies to investigate factors influencing sow longevity (Serenius and Stalder 2006) studies have not provided consistent results in identifying contributing risk factors. The lack of consistency possibly arises because there are different phases in a sow's productive lifetime and contributing risk factors might differ within these phases. For example, changes to correlations between some traits and longevity recorded to different parities (Bunter *et al*. 2010) suggest that associations between traits change as the sow ages. This potentially hinders the ability to identify factors contributing to sow longevity when modelled over the complete trajectory of sow productive life, under either linear or proportional hazards models. This possibility is also not accommodated in most published analyses. The purpose of this study was to use survival analysis methodology, which accommodates censored data, to compare unstratified with stratified models. This approach may better identify important factors affecting sow longevity and will potentially improve estimates of heritability for sow lifetime using commercial Australian data.

MATERIALS AND METHODS

Data. Data on production traits, reproductive outcomes and sow development attributes (weight and fat depth) were available on 3,074 gilts recorded from selection until culling or parity 5 within a single herd. Production traits included lifetime daily gain (ADG, g/day) and back fat (BF, mm) recorded at 20 weeks of age along with average daily feed intake (ADI, kg/day) and feed conversion ratio (FCR, kg/kg) recorded from 21-26 weeks of age. Ongoing records for weight (WT, kg) and fat depth (FT, mm) were obtained from up to 19 recording events, as described in Bunter and Lewis (this proceedings). Reproductive data included total born (TB) at parity 1. Dates of birth and removal were used to calculate the productive life (LPL) of each sow. Approximately 9% of the sows were still present in the herd when the data were obtained, and were therefore censored for LPL. Of the 3,074 gilts selected initially, 60% entered the breeding herd and 41% had

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more than one litter. Gilts represented 467 sires and 2,478 dams. The pedigree was extended back four generations, and contained 6,012 animals in total.

Analysis. Analyses were undertaken with the Survival Kit software Version 6.0 (Ducrocq *et al.* 2010) using the Cox proportional hazards model. To obtain separate hazard functions for different phases and to better identify factors associated with LPL, sows were allocated to three separate strata according to the phase in which they were culled: 1) selected gilts that did not reproduce within the herd, 2) sows that only had a single litter in the herd, and 3) sows that had more than one litter within the herd. The significance of time independent covariates (ADG, BF, ADI and FCR) was then tested separately within each stratum by defining new covariates by strata (eg ADG_1 to ADG_3). For example, for sows within strata 1, ADG_1=ADG, whereas for sows in strata 2 or 3, the value for ADG_1 was the mean of ADG_1, and so on for other strata. Records obtained repeatedly through a sows lifetime (ie WT and FT) were fitted as time dependent covariates. Contemporary group (year-month of selection: 17 levels) was fitted in all models. The data were also analysed without explicitly fitting separate strata within the model, but still using the stratified covariates as defined above. Heritability estimates (on the liability scale) were obtained from both analyses under an animal model, using methods outlined in Meszaros *et al.* (2010), to ascertain the genetic contribution to sow survival within the herd.

RESULTS AND DISCUSSION

Solutions for contemporary group effects suggest that gilts that were selected within winter months had a reduced risk of being culled compared to those selected in spring or summer (-0.33 vs -0.21 and -0.20). Since mating commences approximately three months later, this advantage possibly arises due to commencing breeding in cooler weather. Conception and farrowing rates of gilts reduces with mating at higher temperatures (Paterson *et al.* 1978) which increases their risk of culling. With respect to time independent covariates, the only significant covariates were ADI_1 and FCR_1 within strata 1, and total piglets born in parity one ($TB1_2$) fitted within strata 2. Therefore, production attributes were generally associated with early in life outcomes, but were of less relevance for survival to later parities. Sows with increased average daily intake and lower FCR (improved efficiency) were less likely to be culled in strata 1 (risk solutions were: -0.35 and 0.30, $P<0.0001$). Feed intake is generally an indicator of both good growth and health, attributes which should assist gilts to enter into the reproductive herd. Within strata 2, increased total born in parity one reduced the risk of removal prior to the second parity (risk solution: -0.032, $P=0.02$). Of the time dependant covariates only fat depth was significant ($P<0.0001$), although both ADG and WT also approached significance ($P<0.06$). Higher fat depths throughout the sow's productive life significantly reduced the risk of culling (solution: -0.026), while increasing WT also marginally reduced the risk of culling (solution: -0.002). These outcomes generally confirm the previous results of Bunter *et al*. (2010) who suggested that fat depth was indicative of sufficient energy reserves for sows to support their own needs and that of their litter, reducing their risk of culling. This result is very important from both breeding and production standpoints since selection is generally for leaner pigs and restrictive feeding systems are typical for gestating sows, both of which could inhibit fat deposition in sows and thus their survivability within the herd.

The survival curves and hazard estimates at specific time points are shown in Figure 1. Results demonstrate that the hazard of removal is not constant either within or across strata, and at the end of each strata the probability of removal is very high. Within strata one, the spikes in hazard estimates coincide with culling just prior to and shortly after transfer to the mating facility (~200 days), often due to locomotion problems. At 275 days, another hazard spike occurs when gilts are typically culled for failing to show estrus. Finally, above 300 days, sows identified as not pregnant will be immediately culled, along with forced culling due to late abortion or increased mortality rates of sows prior to the first farrowing. These results demonstrate that in the first strata gilts are susceptible to failure from multiple causes. For strata two the survival curve was generally smoother. However, more diffuse spikes in hazard estimates reflect elevated culling rates in the first lactation, at weaning, and following time points where a failed rebreeding can be identified. Finally, results from strata three (containing the group of sows that farrowed more than once) show a fairly constant hazard between 506 and ~1000 days; a time period which covers successive breeding cycles up to weaning in parity 5. After this age, dips in the survival curve support heightened hazards at weaning and/or rebreeding in each parity. Therefore, specific parities carry different risks in terms of health and allocation of resources that could be to the detriment of a successful re-breeding in the next. Moreover, there are periods of limited risk within every parity, which generally coincides with the time periods when sows are thought to be pregnant.

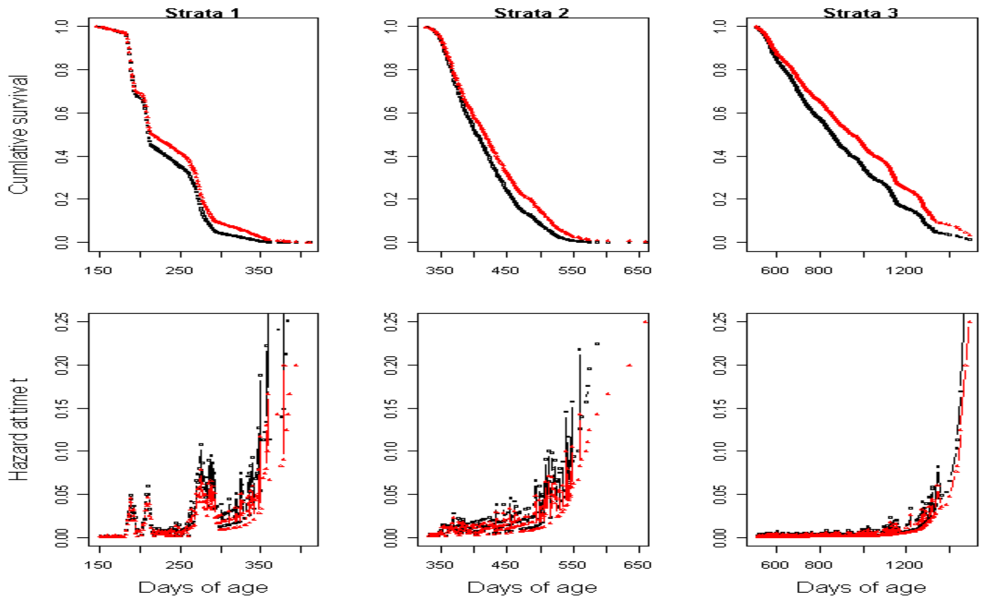

Figure 1. Estimated survival curves and hazard rates from the Cox analysis by strata. Estimates are from the Cox (□) and Kaplan-Meier (Δ) functions.

The survival curve and estimated hazard rates for the model without stratification are shown in Figure 2. Similar patterns are observed with respect to hazard spikes, but they are much less evident over the longer time frame when a single hazard function is fitted. Further, the covariates of ADI_1 and $TB1_2$ were no longer statistically significant, while FT and FCR_1 increased in significance. Over the full course of potential LPL and after accounting for contemporary group, fat depth and feed conversion efficiency were the most important recorded traits influencing LPL. It seems likely that under a restricted feeding regime, which occurs through much of a breeding sow's lifetime, sows which both store energy as fat and make efficient use of feed are advantaged within the production system and are therefore less likely to be culled.

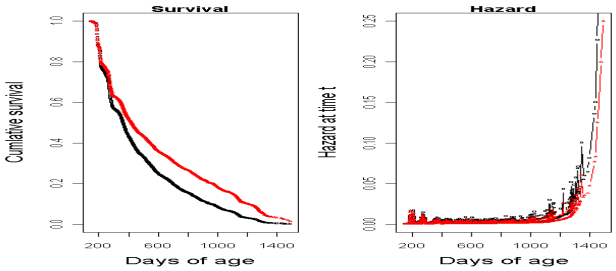

Figure 2. Estimated survival curve and hazard rates for a model without separate strata (see Fig. 1 for legend).

The heritability estimate for liability was 0.04±0.001 from both the stratified and unstratified models used in this study. This estimate was lower than the average of those presented in the review by Serenius and Stalder (2004), who covered several trait definitions and forms of analyses, and Meszaros *et al.* (2010) from a survival analysis. However, the covariates fitted here are all heritable traits in their own right, suggesting that contributions to heritability for LPL from these traits (via genetic correlations) have at least partially been removed in our models where they are fitted as covariates. When all risk factors were removed from the analysis (ie only contemporary group was fitted) the heritability estimate from an unstratified model was 0.09±0.001, more typical of estimates from other studies.

CONCLUSIONS

This research supports previous findings (Bunter *et al*. 2010) that sow fatness, as indicated by fat depth, is an important contributor to sow survival and productivity within a commercial herd with a relatively heavy lean sow genotype. Strategies to maintain fat levels of breeding sows could include easing selection pressure within maternal lines for leanness attributes combined with appropriate nutritional and environmental management for the breeding sow. Addressing causes of high periods of risk early (before entry and parity 2) in a sows potential productive lifetime could significantly improve sow lifetime productivity, given the relatively low hazard for culling between parities two to five.

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