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Survival analysis of piglet pre-weaning mortality

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ABSTRACT: Survival analysis methodology was applied in order to analyse sources of variation of preweaning survival time and to estimate variance components using data from a crossbred piglets population. A frailty sire model was used with the litter effect treated as an additional random source of variation. All the variables considered had a significant effect on survivability: sex, cross-fostering, parity of the nurse-sow and litter size. The variance estimates of sire and litter were closed to 0.08 and 2 respectively and the heritability of pre-weaning survival was 0.03.

Key words: Piglet, Pre-weaning mortality, Survival analysis.

INTRODUCTION - On average 12% of the total number of piglets die before weaning and half these losses happen during the first three days of life (Casellas et al., 2004). Because this aspect is relevant both for ethical and economical implications (Grandison *et al.*, 2005) and for the acceptability of the production system by the consumer, interest for the enhancement of piglet survival and sow maternal ability is increasing. A number of studies (Grandison *et al.*, 2005; Knol *et al.*, 2002) indicated that exploitable genetic variation exists for pre-weaning piglet survival. Selection for enhancing direct piglet survival is difficult due to the binary nature of the trait and large environmental variance (Knol *et al.*, 2002). Furthermore, several information is lost because piglets dying 1 d or 2 wk after birth are treated alike (Casellas *et al.*, 2004). The development of survival analysis techniques (Cox, 1972; Prentice and Gloeckler, 1978), recently adapted for animal breeding purposes (Ducrocq *et al.*, 1988), offers the opportunity of new approaches to the investigation of pre-weaning piglet survival. The aim of this study was to analyse sources of variation of preweaning survival time and to estimate variance components using data from a crossbred piglets population.

MATERIAL AND METHODS - The data included survival time records of 13,924 crossbred piglets (1347 litters) born from 2000 to 2006 and originated by mating 189 Large White C21 Gorzagri boars with 328 Large White-derived crossbred sows. The registration protocol for newborn litters included individual identification of all piglets, including the stillborn ones, the registration of crossfostering up to weaning, and the registration of piglet mortality. For piglets which died before weaning, survival time was computed as the difference between the date of death and date of birth whereas records of piglets still alive at weaning were considered as censored records. The individual survival time was analysed using survival analysis methodology. The hazard function of an individual was modelled according to the following frailty model: $h(t)=h_o(t)\exp\{\mathbf{x}'(t)\boldsymbol{\beta}+\mathbf{z}'(t)\mathbf{u}\}$ where t is the age (d) at death (uncensored records) or at weaning (censored records), $h_0(t)$ is the baseline hazard function, $\mathbf{x}(t)$ is a vector of possibly time-dependent covariates or indicator variables, $\boldsymbol{\beta}$ is a fixed vector of unknown regression coefficients, $\mathbf{z}(t)$ is a vector of possibly time-dependent covariates or indicator variables, and $\mathbf{u}$ is a random vector of unknown regression coefficients. To check whether assuming a Weibull function as baseline hazard function was adequate (Ducrocq *et al.*, 1988), the plot of $\ln(-\ln[S(t)])$ vs $\ln(t)$, where S(t) is the Kaplan-Meier estimated survivor function, was considered. Because of negative results, the baseline hazard function was left completely unspecified (Cox, 1972) and a Cox model, i.e., a semi-parametric proportional hazard model was used. An additional model, based on Prentice and Gloeckler (1978), was applied because it is well adapted for analyses of short periods of time and high incidence of ties in failure times. This model does not make any assumptions about the baseline hazard function, but it can be viewed as a fully parametric model that include a time-dependent covariate that changes at

each day of the observed interval of time (Ducrocq, 1999). A frailty sire model was used and variance components were estimated using the Bayesian approach described by Ducrocq and Casella (1996). The model included also the random effect of the litter which was treated as a time-dependent effect. A normal prior for sire effects and a log-gamma prior for litter effects were assumed. The fixed effect of cross fostering (yes or not), sex (male or female) and year-month of birth (72 levels from July 2000 to July 2006) were included in the model as time-independent covariates. Parity of the nurse sow (1, 2, 3, 4, 5, 6 and 7 or more) and litter size class (≤ 5 piglets, from 6 to 8, from 9 to 11, from 12 to 14, and ≥ 15 piglets) were included as time-dependent covariates. Hypothesis testing was performed via likelihood ratio tests. All analyses were carried out using the "Survival Kit" software, version 3.12 (Ducrocq and Solkner, 1994).

RESULTS AND CONCLUSIONS – In total 14% of the records were uncensored, with an average survival time of 6 d. Estimated hazard ratios (HR) of fixed covariates included in the models are in Table 1. The sex of the piglet was important for its survival: the female piglet had 19% (HR = 0.81; $P<0.001$) less risk of dying than the male piglet.

Table 1. Cox model estimates of regression coefficients and hazard ratios (HR) for fixed covariates affecting piglet pre-weaning survival.

Covariate	Regression coefficient (β)	*P*	HR	95% HR confidence interval	
				Lower bound	Upper bound
Sex		***			
- male	reference		1.000		
- female	-0.210		0.811	0.740	0.887
Crossfostering		***			
- not reference	1.000				
- yes	-0.490		0.613	0.557	0.673
Parity		**			
- 1	0.022		1.022	0.879	1.188
- 2	Reference		1.000		
- 3	-0.155		0.856	0.732	1.001
- 4	-0.268		0.765	0.643	0.908
- 5	-0.217		0.805	0.664	0.975
- 6	-0.124		0.883	0.746	1.045
- 7 or more	-0.149		0.861	0.727	1.019
Litter size		***			
-≤5	1.343		3.830	3.148	4.659
-from 6 to 8	0.150		1.162	0.991	1.361
-from 9 to 11	Reference		1.000		
-from 12 to 14	0.341		1.407	1.245	1.588
- ≥15	0.467		1.596	1.285	1.979

*** P < 0.01; *** P < 0.001.*

The cross-fostering had a positive influence on the survival chances of piglets ($P<0.001$). The survivability of piglets increased with the parity of the nurse sow ($P<0.001$) up to the fourth parity. As evidenced by several authors (Knol *et al.*, 2002; Grandison *et al.* 2005), further increases of parity after the fourth farrowing did not enhance pre-weaning survival. The probability of survival decreased ($P<0.001$) for piglets joining small (n. of piglets ≤ 5; HR = 3.96), large (from 12 to 14 piglets; HR = 1.410) or very large (n. of piglets ≥ 15; HR = 1.609) litters in comparison with litters of intermediate size (from 6 to 11 piglets). This result is in agreement with those from Grandison *et al.* (2005)

and Knoll *et al.* (2002). The cohort effect (year-month of birth) had a marked influence on piglet survival. The mortality rate changes every year and also in different months of the same year due to several sources of variation such as climate, epidemiologic and management effects. The estimates for year-month classes hazard ratios are not presented, but their magnitude did not evidence any consistent seasonal effect over years. Variance components and heritability estimates are reported in Table 2. The estimated variance for litter effects, was higher than that of the sire. A random litter effect can account for infectious diseases, like diarrhoea, and incidentals like diseased udders, which affect all piglets in a litter.

Table 2. Estimates of variance components for sire (σ^2_s) and litter (σ^2_l) effects for the Cox model

Parameter[a]	Cox	
	σ^2_s	σ^2_l
Mode	0.058	2.018
SD	0.027	0.223
Effective h^2	0.11	
Equivalent h^2	0.03	

[a] Mode = mode of the marginal posterior density of the estimated variance component; SD = standard deviation of the marginal posterior density of the estimated variance component; Effective h2 = effective heritability (Yadzi et al., 2002), i.e., $h^2=4* \sigma^2_s/(\sigma^2_s + \sigma^2_l)$, where σ^2_s is the mode of the sire variance marginal density and ?2l is the litter variance; Equivalent h^2 = equivalent heritability (Yazdi et al., 2002), i.e., $h^2=4* \sigma^2_s/(\sigma^2_s + \sigma^2_l +1/p)$, where p is the proportion of uncensored records.

Using the formula of Yazdi *et al.* (2002), the estimated heritability, in the unrealistic situation of no censoring, reached a value of 0.11. After correction for the censoring rate (86%), the equivalent heritability was lower (0.03) and similar to estimates reported by several authors (Knoll *et al.*, 2002; Casellas *et al.*, 2004; Grandison *et al*., 2005). In conclusion, the Cox model did not differ significantly from the Grouped data model (estimates not shown). Further studies will be conducted to test different models that should account of other effects involved on survival pre-weaning of piglets.

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