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Effect of within-litter birth weight variation on piglet survival and pre-weaning weight gain in a commercial herd

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Abstract

There are several factors that affect piglet survival and this has a bearing on sow productivity. Ten variables that influence pre-weaning vitality were analysed using records from the Pig Industry Board, Zimbabwe. These included individual piglet birth weight, piglet origin (nursed in original litter or fostered), sex, relative birth weight expressed as standard deviation units, sow parity, total number of piglets born, year and month of farrowing, within-litter variability and the presence of stillborn or mummified littermates. The main factors that influenced piglet mortality were fostering, parity and within-litter variability especially the weight of the individual piglet relative to the average of the litter ($P < 0.05$). Presence of a mummified or stillborn littermate, which could be a proxy for unfavourable uterine environment or trauma during the birth process, did not influence pre-weaning mortality. Variability within a litter and the deviation of the weight of an individual piglet from the litter mean, influenced survival to weaning. It is, therefore, advisable for breeders to include uniformity within the litter as a selection criterion. The recording of various variables by farmers seems to be a useful management practice to identify piglets at risk so as to establish palliative measures. Further, farmers should know which litters and which piglets within a litter are at risk and require more attention.

Keywords: pre-weaning mortality, relative birth weight, litter weight variability, piglets, sow

1 Introduction

Sow productivity is dependent on the sow's ability to produce piglets that survive to weaning (Damgaard *et al.*, 2003; Fix *et al.*, 2010). Piglet mortality is a problem for economic and animal welfare reasons (Tuchscherer *et al.*, 2000). Several factors interact to influence piglet survival, including the intrauterine environment, injuries suffered *in utero* and during farrowing, maternal environment, birth weight, postnatal environment and thermoregulatory ability (Casellas *et al.*, 2004; Wu *et al.*, 2006). Casellas *et al.* (2004) reported that birth weight, relative birth weight within litter, rectal temperature 60 minutes after birth, type of presentation at birth and presence of stillbirths or mummified littermates were the six most important variables that influence mortality. Parity was also reported to increase risk of mortality in pigs (Marchant *et al.*, 2000; Planine *et al.*, 2011). Differences in piglet weight at birth are often maintained or increased throughout lactation (Tokach *et al.*, 2004). The influence of parity is likely to be due to an increase in litter size which, consequently,

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increase variability in piglet birth weight (Zindove *et al.*, 2013). Larger piglets may be more competitive than their lighter littermates (Fix *et al.*, 2010).

It is common practice in the pig industry to cross foster piglets between litters to equalise the number of pigs per litter, minimise birth weight variation and match piglet numbers to number of teats. This is done to enable the smaller, less competitive piglets to achieve adequate milk intake and improve survival rates (Milligan *et al.*, 2002; Damgaard *et al.*, 2003). Cross-fostering, therefore, benefits light litter-mates and decreases the level of piglet aggression. Despite its potential importance to the pig industry, there is relatively little known about birth weight variation within litters and its effects on piglet survival, weight gain and weaning weights. It is expected that a negative relationship exists between survival rate and the variability in the birth weights of piglets in a litter. The economic impact of huge variations in piglets at birth needs to be estimated. Post-weaning growth performance, pig aggression and piglet survival are some of the major indicators of pig herd productivity. Evidence on the vitality and post-weaning growth performance is scant (Canario *et al.*, 2010; Fix *et al.*, 2010; Zindove *et al.*, 2014). The lack of sufficient evidence makes it difficult for farmers and pig breeders to invest in recording individual birth weights of piglets. At the turn of the millennium, the Pig Industry Board of Zimbabwe, whose mandate is to, among other functions, provide genetically improved pigs to farmers, included birth weight variation as a sow trait in their genetic evaluations. The impact of the selection in the commercial herd needed to be characterised to enable sufficient information to be supplied to farmers. The objective of the study was, therefore, to determine the relationship between within litter variation and piglet vitality (survival and growth rate).

2 Materials and methods

2.1 Site

The experimental pigs were part of the commercial herd at the Pig Industry Board (PIB) farm (Arcturus, Zimbabwe). The farm is located 30 km northeast of Harare, in an intensive mixed crop farming area. The site lies approximately 1500 m above sea level. Mean temperature during the warm humid months averages 21 °C, while the cool dry months average 16 °C. The mean annual rainfall is 800 mm.

2.2 Data collection

A total of 29,127 piglet records were collected from 2000 to 2005 at the Pig Industry Board commercial herd. These piglets were produced from 3,332 litters from 270 sows. A total of 27 performance-tested boars were used for breeding. Litters with less than 4 piglets were removed from the analyses. The piglets were from the same dam (Landrace) and sire (Large White) lines. Data recorded was identity of dam and sire, month (MONTH) and year (YEAR) of farrowing, litter size (TNB), parity (PARITY), individual birth weight (BWT), presence of a stillborn or mummified littermate (PRESENCE), sex of piglet (SEX), whether the piglet was fostered in or out of the litter (FOSTERING), month of weaning, whether the piglet survived to weaning (SURV), weaning weight (WW) and the number of piglets weaned (NW). The relative birth weight was calculated as the difference between the piglet birth weight and the mean litter weight. The individual relative birth weight values were standardised (RSTDEV) by dividing them by the litter standard deviation. The within litter variation was calculated as the coefficient of variation of the birth weight (CVBWT) and the average daily gain (ADG) was also calculated.

2.3 Pig management

All gilts and sows were mated through natural service. Both were fed on 2 kg of commercial sow meal containing 160 g crude protein/kg feed and 12 MJ digestible energy/kg feed. Pregnant sows were put into the farrowing houses on day 109 of gestation. The farrowing house was both naturally (via small windows) and artificially illuminated. Water was supplied *ad libitum* through low-pressure nipple drinkers. The creep area was heated using an infra-red lamp from day 110. All pigs in the study were treated in compliance with internationally recognised codes and standards for animal welfare.

2.4 Statistical analyses

BWT and WW, NW and ADG were checked for normality, influential observations and outliers during the PROC GLM procedure via the PLOT=DIAGNOSTICS option using SAS software ver. 9.3 (SAS Institute Inc., 2011). The WW, BWT and ADG were normally distributed while NW had to be normalised through square root transformation. Several independent variables were assessed for correlation. The BWT was correlated to TNB, CVBWT and RSTDEV, while TNB was correlated to CVBWT and not RSTDEV. The CVBWT and

RSTDEV were not correlated. As a consequence, TNB and BWT were dropped from further analysis. The effect of birth weight variation on NW, ADG and piglet WW was analysed using PROC GLM procedure (SAS, 2011) using the model:

$Y_{ijklmnop} = \mu + P_i + S_j + C_k + O_l + A_m + M_n + R_o + E_{ijklmnop}$

Where $Y_{ijklmnop}$ is the response variable being NW, ADG and WW; μ is the overall mean common to all observations; P_i is the effect of the i^{th} parity ($i = 1 \ldots 10$); S_j is the effect of the j^{th} sex of piglet (j = male, female); C_k is the effect of the k^{th} CV of birth weight ($k = 0 \ldots 87.5$); O_l is the effect of the l^{th} piglet status (l = fostered or retained in original litter); A_m is the effect of the m^{th} year ($m = 2000 \ldots 2005$); M_n the effect of the n^{th} month (n = January…December); R_o is the effect of the o^{th} RSTDEV ($o = -7.2 \ldots 5.7$); $E_{ijklmnop}$ is the random residual error distributed as N (0,1 σ^2_E). Pairwise comparisons for a few variables of interest were carried out using the PDIFF option in SAS (2011).

An ordinal logistic regression was used to determine the odds of pre-weaning mortality using the PROC LOGISTIC procedure (SAS, 2011):

$$ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_i X_i \ldots \beta_n X_n + E$$

with P being the probability of dying before weaning; β_0 is the intercept; $\beta_i \ldots \beta_n$ are regression coefficients ($\beta_1 \ldots \beta_7$) of regressor variables on $ln\left(\frac{P}{1-P}\right)$; $X_i \ldots X_n$ are regressor variables being, FOSTERING, SEX, RSTDEV, PARITY, YEAR, MONTH, CVBWT and PRESENCE; $\left(\frac{P}{1-P}\right)$ is the odds ratio giving the odds of dying given the above regressor variables and E is the random residual error distributed as N (0, 1 σ^2_E). Regressors that had a high correlation to other regressors were removed from the model. The best model was then chosen using stepwise selection.

3 Results

The parity ranged from 1 to 10, number born alive from 1 to 19 piglets, number born dead (NBD) within a litter ranged from 0 to 11 with the number born mummified (NBM) ranging from 0 to 9. However, the mean NBD (±SD) and the mean NBM (±SD) of 0.4±1.02 and 0.1±0.47 showed that relatively few litters had stillborn or mummified littermates. The mean percentage of males within one litter was slightly higher compared to females. The individual birth weight ranged from 0.1 to 4 kg with an average of 1.5±0.36 kg. The within-litter variability ranged from 0 to 87.5 % while absolute relative birth weight ranged from –1.4 to 2.3 with the RSTDEV ranging from –7.2 to 5.7 (Table 1).

Parity, year of farrowing, month of farrowing and piglet fostering status affected ADG, WW and NW ($P < 0.001$). within-litter variability and the RSTDEV affected NW ($P < 0.001$), but not the ADG and the WW ($P > 0.05$). The sex of the piglet influenced ADG and WW, but not NW ($P < 0.05$; Table 2).

Average daily gain, WW and NW were generally low at parities 1 and 2, peaked between parities 3 and 6 and declined thereafter. The variables were lowest between April and May but were fairly stable throughout the year. The year of weaning significantly ($P < 0.05$) affected WW, ADG and NW, with the year 2002 showing the lowest level for all three variables. Cross fostering significantly reduced the ADG, the WW and the NW ($P < 0.01$; Table 3). There was a slight increase in WW with increasing RSTDEV (Fig. 1). There were fewer piglets whose RSTDEV was more than 2 SD units from the litter mean. As a consequence, the standard errors for these observations were high.

Table 4 shows the factors that influence piglet mortality. The CVBWT and the presence of a stillborn or mummified littermate did not affect piglet mortality ($P > 0.05$; Table 4). All OR estimates were relatively weak (between 1 and 1.50) or moderate (1.5 to 3.0; Table 4). The standardised relative birthweight influenced mortality with those piglets whose RSTDEV is below zero having the highest risk. The risk of dying before weaning increased with an increase in the within-litter variability.

Female piglets had less risk of mortality (0.14) compared to males (0.16; $P < 0.001$). The risk of pre-weaning mortality was highest in parities above 8, moderately high in parities 1 and 2 and lowest in parity 5 ($P < 0.05$). It was also observed that very small litters had the highest risk of pre-weaning mortality, with very large litters having moderate risk and litters of between 10 and 14 having the lowest risk ($P < 0.05$). The YEAR did not affect risk of mortality ($P > 0.05$) but the MONTH had a significant effect ($P < 0.001$). The cold months, with an average temperature of 12 °C had higher mortalities compared to warm months averaging 28 °C.

4 Discussion

Cross fostering is a common practice with three major objectives; to equalise number of piglets per litter, to match piglet numbers to number of teats and to minimise BWT variation (Damgaard *et al.*, 2003). However, the impact of cross fostering on piglet survival has not been adequately described. This study suggests that

Table 1: *Summary statistics of reproductive performance of sows in the commercial herd at the Pig Industry Board, Zimbabwe between 2000 and 2005.*

Variable	*N of records*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Parity	31,446	4.0	2.15	1.0	10.0
Number born alive	29,127	9.5	2.62	1.0	19.0
Number born dead	870	0.4	1.02	0.0	11.0
Number mummified	532	0.1	0.47	0.0	9.0
Total number born	29,127	10.0	2.69	1.0	19.0
Number of males within litter	29,127	5.6	2.23	0.0	19.0
Percent males within litter	29,127	51.9	16.85	0.0	100.0
Individual birth weight (kg)	29,127	1.5	0.36	0.1	4.0
CV birthweight within litter (%)	29,127	16.7	8.69	0.0	87.5
Total litter birth weight (kg)	3,332	16.0	4.26	0.5	39.6
Relative birth weight (kg)	29,127	0.0	0.26	–1.4	2.3
Average birth weight (kg)	29,127	1.5	0.26	0.0	2.9
Within litter standard deviation	29,127	0.2	0.12	0.0	0.7
Standardised relative birth weight	29,127	0.0	0.96	–7.2	5.7
Weaning weight (kg)	27,725	6.8	3.94	1.3	11.0
Number weaned	27,725	8.4	2.19	0.0	24.0
Age at weaning (days)	27,725	33.6	2.99	14.0	66.0

Table 2: *Factors affecting piglet average daily gain (ADG), weaning weight (WW) and number weaned (NW).*

Variable	*DF*	*ADG*	*WW*	*NW*
Parity	9	***	***	***
Year of farrowing	5	***	***	***
Month of farrowing	11	***	***	***
Fostering	1	***	***	***
CVBWT	6	0.5617	0.4139	***
RSTDEV	64	0.4984	0.6102	***
Sex	1	*	*	0.2288
Male percentage	9	0.6591	0.5873	***

* $P < 0.05$; *** $P < 0.001$; CVBWT = coefficient of variation of the birth weight; RSTDEV = standardised relative birthweight

Table 3: *Effect of cross fostering on average daily gain (ADG), weaning weight (WW) and number weaned (NW).*

	Nursed in original litter	*Fostered*
n	24961	4316
ADG (kg/day)	0.16^a ±0.001	0.15^b ±0.002
WW (kg)	6.80^a ±0.030	6.37^b ±0.078
NW	8.51^a ±0.014	8.30^b ±0.047

Means in the same row with different superscripts differ ($P < 0.01$)

Table 4: *Odds ratio estimates and confidence limits for factors affecting piglet mortality.*

Effect	*Odds Ratio Estimate*	*95% Wald Confidence Limits*	
RSTDEV	1.478	1.427	1.531
Fostering	1.832	1.644	2.042
CVBWT	0.973	0.969	0.976
PARITY	1.022	1.006	1.038
SEX	1.164	1.087	1.246
MONTH	0.981	0.970	0.991
YEAR	1.039	1.014	1.065

RSTDEV = standardised relative birthweight; FOSTERING = whether the piglet was fostered or not; CVBWT = within litter variation of body weight; PARITY = parity; SEX = sex of piglet; MONTH = month of farrowing; YEAR = year of farrowing.

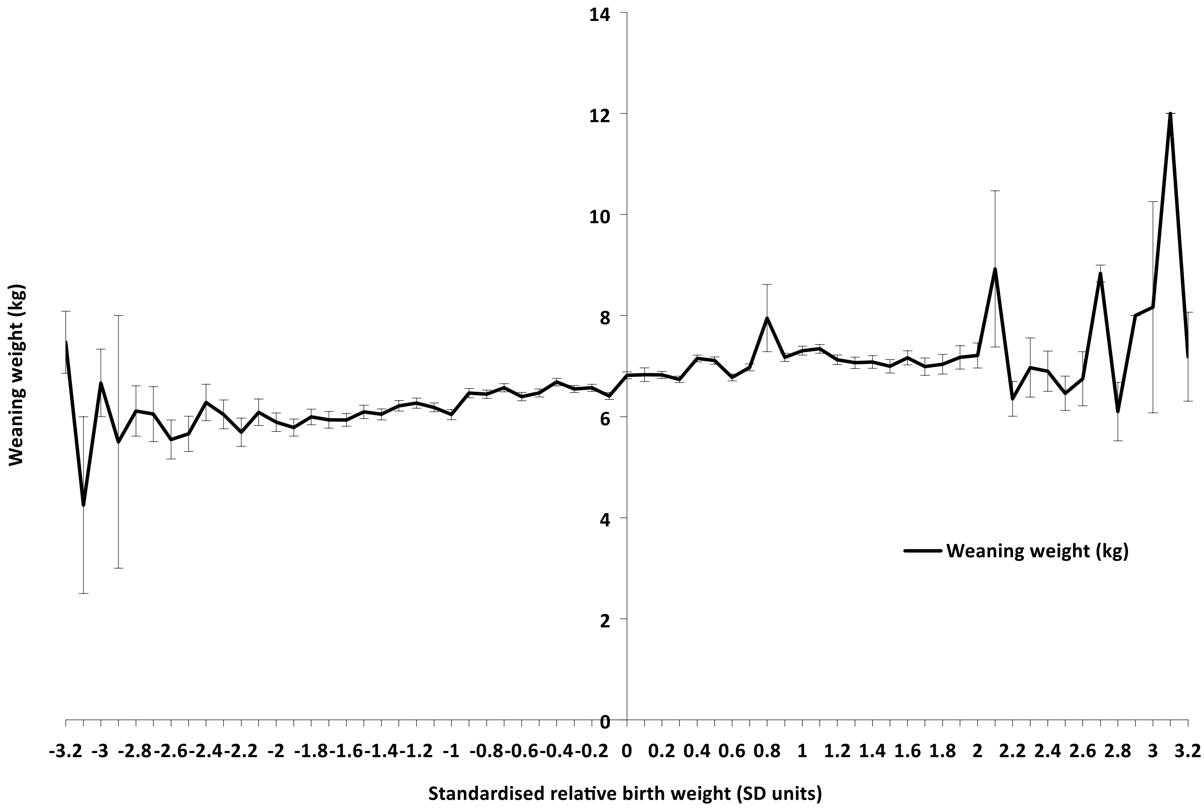

Fig. 1: *The effect of standardised relative birth weight (RSTDEV) on weaning weight (WW).*

the fostered piglets have a higher probability of dying before weaning. This could be due to failure to adjust to the new littermates leading to generalised poor vitality as shown by lower weight gains. In addition, some cross fostered piglets were transferred from sows that had shown poor reproductive and mothering ability which have a permanent impact on their performance.

The increase in probability of death with CVBWT was expected and agrees with various studies (Marchant *et al.*, 2000; Milligan *et al.*, 2002; Damgaard *et al.*, 2003). The reasons for this are straightforward in that the higher the variability, the higher the proportion of small piglets which are less competitive compared to their heavier littermates.

The influence of parity on ADG, WW and NW was expected. Younger sows tend to have smaller litters and smaller piglets given that they have to allocate resources to both pregnancy and growth. The older sows (above parity 7) may have reduced uterine efficiency leading to lower allocation of resources to the foetuses affecting both their number and postnatal vitality (Damgaard *et al.*, 2003).

The effect of the month of weaning on ADG, WW and NW may be due to the weather changes that occur throughout the year. In Zimbabwe, the rainy season starts in late October and ends in March, while the cooler dry period occurs from May to August. The influence of year of farrowing is related to feed availability. The years 2001 to 2003 were drought years in Zimbabwe and in southern Africa as a whole, thus feed was scarce hence the observed impact on ADG.

Male piglets are expected to grow faster than females, so litters dominated by males were expected to grow faster than female dominated litters. A similar observation was made in this study. Sex had a significant effect ($P < 0.05$) on ADG. The observation is in line with literature reports that differences in weights at birth tend to be maintained to weaning (Tokach *et al.*, 2004).

This study could show that the individual birth weight had a higher impact on piglet survival than relative birth weight. Despite the fact that males tended to be heavier than females and had higher RSTDEV, there is obvious sexual dimorphism with regard to survival to weaning with male piglets suffering higher mortalities than females. This concurs with findings by Lay Jr. *et al.* (2002) and Canario *et al.* (2006), who reported that females have a greater chance of survival than males. In terms of species survival, a higher wastage among males can be tolerated since each male can sire thousands of offspring in its lifetime. However, the mechanisms underlying higher female survival have not been adequately described even though Lay Jr. *et al.* (2002) hypothesised that males are more susceptible to stress due to higher basal cortisol levels. That the higher birth weights of males do not give them a survival advantage tends to support the hypothesis that the differences between the sexes are physiological.

The lack of association between the probability of dying and the presence of stillborn or mummified littermates was unexpected. The expectation was that whatever had caused the death of these littermates will have a negative influence on the remaining siblings (Casellas *et al.*, 2004). These workers hypothesised that even though the causes of mummification are varied, the presence of mummies can lead to changes in the uterine environment that have, as a consequence, a negative impact on the post natal vitality of siblings. The findings of this study may have been affected by the relatively few incidences of stillbirths and mummies compared to the total size of the dataset. However, this is an area that warrants further investigation.

The relationship between parity and piglet mortality has been reported before for incidence of stillbirths during farrowing (Canario *et al.*, 2006). It seems the mechanisms that predispose piglets to stillbirth are similar to those that influence mortality before weaning. These are mainly the lack of physiological maturity of gilts and younger sows and the poorer mothering ability of older sows that may be overweight.

Various environmental factors such as temperature and rain are expected to influence piglet survival as they affect the amount of energy expended on thermoregulation (Wu *et al.*, 2006) and incidence of disease. The mortality risk in this study was highest in the cooler months of the year. The lack of effect of the year of farrowing might be due to the lack of relatively low genetic progress in selecting for a higher litter size in the herd so that the five years considered were insufficient to produce a measurable impact.

5 Conclusions

There are several factors that increase mortality risk. Variability within a litter (a litter trait) and the deviation of the weight of the individual piglet from the litter mean (a piglet trait) influence survival to weaning. Pig breeders should, therefore, include uniformity of the litter as a selection criterion while farmers should know which litters and which piglets within a litter are at risk and require more attention. Further, although fostering as a management tool is widespread, piglets that are fostered out are at risk. The relative merits of unforced fostering have to be investigated.

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