Pig characteristics associated with mortality and light exit weight for the nursery phase

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Abstract — One thousand and ten weaned pigs that were reared in 1 nursery in Iowa from weaning (17 ± 2 days) until 10 weeks of age were evaluated. A weaning weight threshold of 3.6 kg maximized the sensitivity and specificity to correctly predict the likelihood of dying or being light in weight at exit from the nursery (≤ 14.5 kg). Weaning weight ≤ 3.6 kg (OR = 2.92), barrow (OR = 1.75), and sow unit (A versus B, OR = 2.14) were significant predictors of mortality in the nursery. Birth weight ≤ 1.0 kg (OR = 2.66), weaning weight ≤ 3.6 kg (OR = 8.75), gilt (OR = 1.4), sow unit (OR = 2.38), and gilt as nursing sow at weaning (OR = 1.66) were significant predictors of being lightweight at nursery exit. Eighteen per cent of the nursery deaths and almost half of lightweight nursery pigs could be prevented if there were no lightweight pigs at weaning.

Résumé — Traits caractéristiques des porcs associés à la mortalité et au faible poids au départ pour la pouponnière. Mille dix porcelets sevrés gardés dans une porcherie de post-sevrage de l'Iowa entre le sevrage (17 ± 2 jours) et l'âge de 10 semaines ont été évalués. Un poids limite de 3,6 kg au début du sevrage maximisait la sensibilité et la précision de la prévision des risques de mortalité ou de faible poids au départ de la pouponnière (≤ 14,5 kg). Le poids au sevrage ≤ 3,5 kg (RC = 2,92), la castration chez le mâle (RC = 1,75) et la provenance de la truie (A versus B, RC = 2,14) constituaient des indicateurs significatifs de mortalité en pouponnière. Le poids à la naissance ≤ 1 kg (RC = 2,66), le poids au sevrage ≤ 3,6 kg (RC = 8,75), la première mise bas (RC=1,4), la provenance de la truie (RC = 2,38) et la première lactation (RC = 1,66) constituaient des indicateurs significatifs de faible poids en fin de post-sevrage. Dix-huit pour cent des morts en post-sevrage et près de la moitié des porcelets de faible poids en pouponnière auraient pu être évités s'il n'y avait pas eu de porcelets de faible poids au sevrage.

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Introduction

Though it has been argued that some pigs at weaning need greater care or specific therapeutic interventions, the identification of these pigs is often subjective and inconsistent. Criteria are needed for identifying at weaning those pigs that have a lower likelihood of survival and low growth during the nursery phase.

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Mean weaning weight and age are monitored because these factors can affect postweaning growth performance (1–4) and influence nursery feed intake (5). Weaning weight is predetermined by factors such as birth weight, cross fostering, and milk intake during the suckling phase (6–8). It is also related to litter factors such as litter size and birth weight variability (8).

To document estimates for characterizing pigs that are at a higher risk of dying after weaning or of being lightweight at nursery exit, a study was conducted at 1 nursery site. The goals were to make an evaluation of different weaning-weight categories in order to assign risk of dying or being a lightweight pig at nursery exit, and to describe the association between several individual pig factors regarding mortality and the odds of being in the lower third of the weight distribution at 10 wk of age (< 14.5 kg).

Materials and methods

Weaned pigs from 2 sow units (2500 year inventory) in southern Iowa were selected for this study. The units were located within a mile of each other; they had the same ownership and management, with common building

Table 1. Characteristics of the population studied

Population characteristics	Frequency (%)	Mean (*s*)
Birth weight (kg)	—	1.36 (0.34)
Weaning weight (kg)	—	3.95 (1.03)
Nursery weight at week 10 (kg)	—	16.68 (4.10)
Weaning age (days)	—	17.0 (2)
Nursery mortality	7.03	—
Sow unit A	56.93	—
Barrow	48.51	—
Gilt progeny[a]	22.08	—
Nursed by gilt[bc]	30.22	—
Cross — fostered	59.27	—

n = 1010
s — standard deviation
[a]Parity of the dam
[b]Parity of the nursing dam at weaning
[c]*n* = 874

design, breeding stock supply (Cotswold Euro Gilt), and feed and vaccination programs. In both farms, porcine reproductive and respiratory syndrome (PRRS) was endemic. Sows were vaccinated against infection by PRRS virus (PRRSV), and *Mycoplasma hyopneumoniae* during gestation. In both sow units, the preweaning mortality was approximately 14% and clinical coccidiosis was the major disease concern in the progeny. During the last week of July 2001, newborn pigs were ear tagged and weighed before being cross-fostered (9). Cross-fostering was permitted according to defined criteria established at the farm. However, for the pigs included in the study, the dam's ear tag number was recorded before the pigs were mixed. At weaning (17 ± 2 d), 1010 pigs from 198 litters (median = 7 pigs/litter) were weighed and the nursing sow's identification number was recorded.

After weaning, the pigs were reared off-site in 2 (C and D) curtain-sided wean-to-finish barns joined by a covered hallway by their sides. Each barn had 36 pens with wet-dry feeders and a capacity for 28 pigs/pen. The pigs from both sow sources (A and B) were transferred to the nursery site in the same truck, and complete comingling was accomplished before they were allocated to different pens according to their weight and gender. The feeding program was a standard 4-phase nursery diet (24%-22%-20%-18% crude protein), with corn and soybean meal as the major ingredients. Four pens at the center of each nursery barn were used to hold sick pigs during their treatment. Recovered pigs were returned to their original pen. All dead pigs were identified and the date of death was recorded. No pigs were culled during the study.

The variables used for analysis were birth weight (≤ 1 kg versus > 1 kg), weaning weight (≤ 3.6 kg versus > 3.6 kg), and weaning age (≤ 17 d versus > 17 d), gender (gilt versus barrow), parity of the farrowing dam (gilts versus sow), parity of the nursing dam at weaning (gilt vs sow), sow unit (A versus B), cross-foster status (Y versus N), and barn (C versus D). A pig was classified as cross-fostered (Yes) when the nursing sow ear tag did not match with the dam ear tag (Table 1). Weaning age category (≤ 17 versus > 17 d) was included in the final models, regardless of its statistical significance.

Weaning weights were allocated to binary categories of ≤ or > than 3.2, 3.6, 4.1, 4.5, and 5.0 kg, which included the whole range of the weaning weight distribution. Sensitivity and specificity were calculated to predict death or lightweight at exit for each weaning weight cut-off classification. A pig was classified as a lightweight pig at exit when the exit weight was lower than the 30th percentile (14.5 kg) at 10 wk of age. Sensitivity was defined as the probability of having a weaning weight ≤ the cut-off i, given the pig died (or was lightweight at exit); specificity was defined as the probability of having a weaning weight above the cut-off i, given the pig survived (or was not lightweight at exit).

Cumulative weekly survival from weaning through 10 wk of age was estimated by using the Kaplan-Meyer method (Proc Lifetest; SAS, Cary, North Carolina, USA) (10). Survival differences were assessed with the log-rank test (10). Univariate odds ratio were calculated for each factor analyzed (Proc Freq; SAS) and adjusted odds ratios (Proc Logistic; SAS) were estimated by fitting a logistic model (11), as follows: $E(\pi_i)$ with $\pi_{i\sim}$ Binomial, $\text{Log}(\pi_i/(1 - \pi_i)) = X_i\beta$, where π_i is the probability of dying or being lightweight at nursery exit (11). Deviance and Wald's test were used to select the best set of independent variables (12), including the evaluation of second order interaction. Those predictors were used to fit a logistic mixed model, including litter as random effect (Glimmix Macro; SAS) (12). The mixed model fitted was as follows: $\text{Log}(\pi_{ij}/(1 - \pi_{ij})) = X_{ij}\beta + Z_{ij}u_j$ with $u_{j\sim}$ Normal $(0,\sigma^2)$, where i and j refered to pig and litter, respectively. The response variable is a linear combination of fixed ($X_{ij}\beta$) and litter-specific random effects ($Z_{ij}u_j$), (12,13). The vector of random effects ($u_1,\ldots,u_{138}$) represents how much the risk of dying or being a lightweight pig at exit for the litters deviates from the population mean (12,13). The litters included in the analysis were those with more than 3 pigs available at weaning (90.09% of the pigs recruited).

Population attributable fraction (PAF) was estimated to determine the proportion of cases, death or lightweight pigs at week 10, that could be attributed to each risk factor identified (14–16). The PAF was defined as $1 - \Sigma_j (P_j/R_j)$, where P_j was the proportion of all deaths in stratum j (sow unit A) and R_j was the estimated relative risk (odds ratio from the logistic model) in stratum j.

Results

A trade-off of the sensitivity (Se) and specificity (Sp) to discriminate dead from surviving pigs according to the different cut-off used was observed (Figure 1). A threshold of 3.6 kg maximized the Se and Sp of weaning weight status (17-day-old piglets) as a predictor of mortality during the nursery (Se = 44.5%, Sp = 36%, Figure 1). The same maximization of the weaning weight threshold was observed when light weaning weight status was evaluated as the criterion to discriminate pigs below and above 14.5 kg at week 10 of age (Se = 79%, Sp = 66%, Figure 2).

Survival decreased after weaning, mainly during the first 4 wk after placement. Lower levels of survival were observed for barrows (Figure 3, *P* = 0.032), as well as for pigs with light weaning weight (≤ 3.6 kg) (Figure 4, *P* = 0.002). Differences in survival between genders and weight categories (≤ 3.6 kg versus > 3.6 kg) were

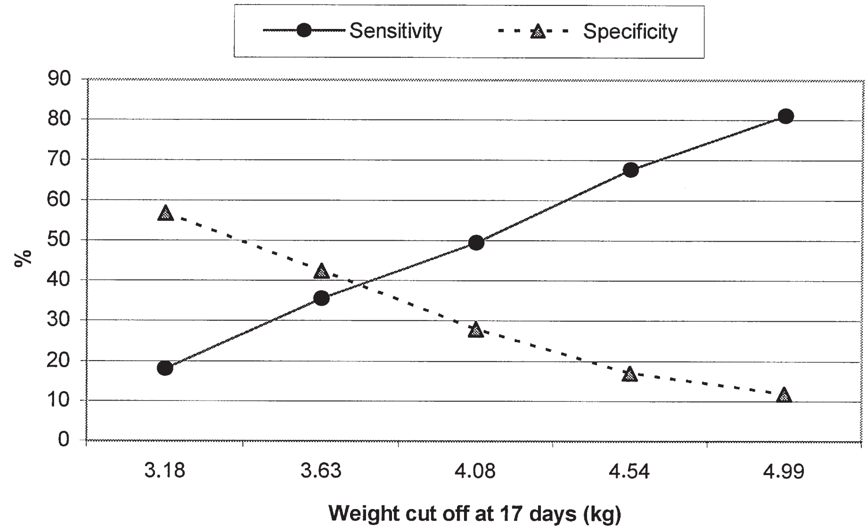

Figure 1. Sensitivity and specificity of predicting death and survival of pigs during the nursery (17 d to 10 wk) by using different weight thresholds at weaning (17 ± 2 d).

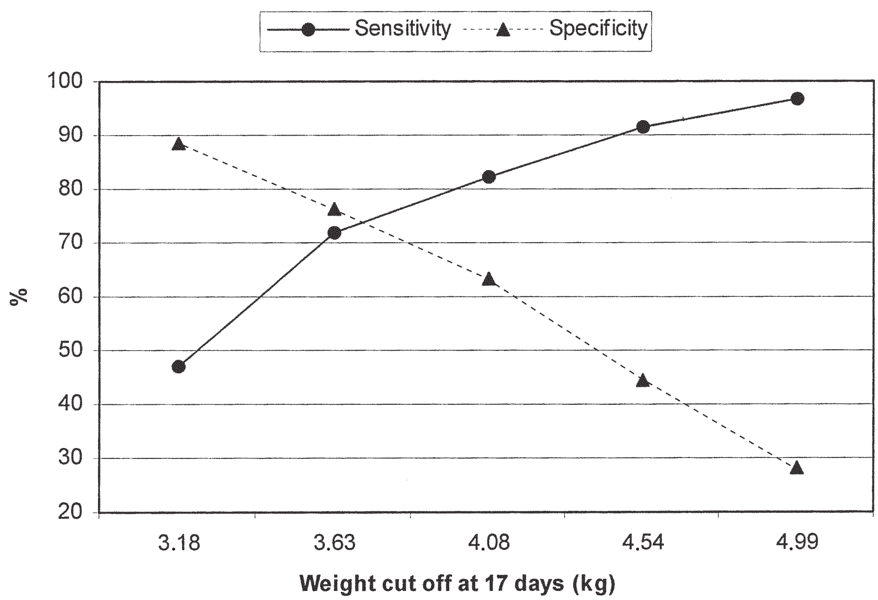

Figure 2. Sensitivity and specificity of detecting light (≤ 14.5 kg) and heavy (> 14.5 kg) weight pigs at exit from nursery (10 wk old) by using different weight thresholds at weaning (17 ± 2 d).

Note: the criterion to define light and heavy pig at exit was 14.5 kg

certainly not stable across the nursery period. Such differences become progressively larger from weeks 1 to 4 and remain relatively stable after that period (Figure 3).

The univariate analysis showed no statistical association of parity variables (gilt versus sow), barn (C versus D), weaning age (≤ 17 d versus > 17 d), and cross fostering (Y versus N) on nursery mortality (Table 2). But the odds ratio were all greater than 1 and statistically significant for birth weight (≤ 1 kg versus > 1 kg), weaning weight (≤ 3.6 kg versus > 3.6 kg), sow unit (A versus B), and barrows (barrow versus gilts).

Parity of the dam (gilt versus sow), barn (C versus D), weaning age (≤ 17 d versus > 17 d) and sow unit (A versus B) were not associated with lightweight status at 10 wk of age (Table 2). Conversely, birth weight (≤ 1 kg versus > 1 kg), weaning weight (≤ 3.6 kg versus > 3.6 kg), cross fostering (Y versus N), sow unit (A versus B), gilts (gilt versus barrow), and gilts as nursing sow at weaning (gilts versus sow) significantly increased the odds of being a lightweight pig at the end nursery phase (10 wk of age) (Table 2).

All factors were evaluated in the multivariate model. Weaning weight and gender, as pig factors, together with sow unit of origin, were associated with mortality in the multivariate model. The risk of dying was approximately 3 × higher for lightweight weaning pigs (≤ 3.6 kg versus > 3.6 kg), and 2 × for barrows and sow unit (A versus B) (Table 3). The magnitude of the risk of dying for light weaning weight did not change significatively when gender or sow unit of origin was evaluated as a 2nd order interaction terms.

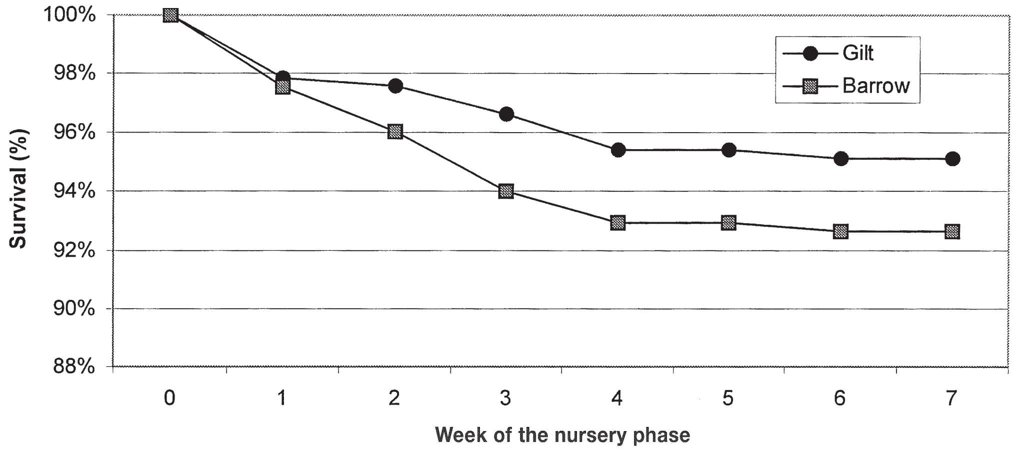

Figure 3. Survival during the nursery phase (17 d to 10 wk) by pig gender.

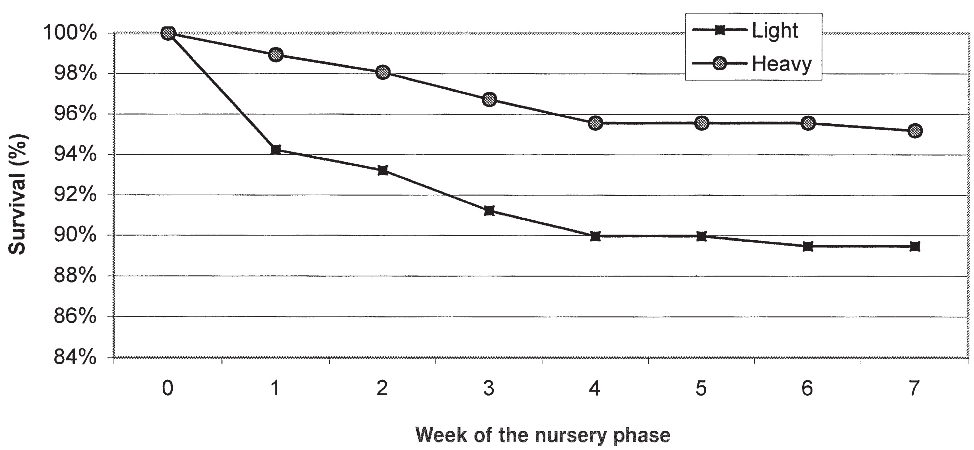

Figure 4. Survival during the nursery phase (17 d to 10 wk) for pigs with weaning weight above (heavy) and below (light) 3.6 kg.

Light birth and weaning weights, as well as sow unit of origin and the nursing sow parity at weaning, remained significantly associated with lightweight status at 10 wk of age in the multivariate model (Table 3). As observed in the mortality model, no evidence of interaction between the factors included in the model was found (Tables 2 versus 3).

Since the variables found associated in both models (mortality and lightweight at the end of the nursery phase) showed no interaction, a consistency between the adjusted odds ratio and those estimated by univariate methods was evidenced (Tables 2 versus 3).

The proportion of mortality in this population that could be due to the factors analyzed (population attributable fractions) was about 18.0%, 24.0%, and 22.0%, for light weaning weight ($\leq$ 3.6 kg versus $>$ 3.6 kg), gender (barrows versus gilts), and sow unit of origin (A versus B), respectively (Table 4, upper part). For the lightweight pig cases at week 10 of age ($\leq$ 14.5 kg), 48.0% of the cases could be attributed to light weaning weight ($\leq$ 3.6 kg versus $>$ 3.6 kg), 24.0% to gilt as a nursing sow at weaning (gilts versus sow), 26.0% to low birth weight ($\leq$ 1 kg versus $>$ 1 kg), and 21.0% to sow unit of origin (A versus B) (Table 4, lower part).

Discussion

Light weight at weaning is a better predictor for being light weight at nursery exit than for death, although a threshold of 3.6 kg was optimum for both outcomes. Weaning weight of less than 3.6 kg at 17 ($\pm$ 2) d may indicate characteristics of the pig that increases its propensity to die or have an undesirable exit weight.

Previous reports have described that chances of survival increased when weaning weight was greater than 3.6 kg (approximately 3 wk old) (17) and for weaning weight greater than 4.2 kg (weaning age range between 12 and 21 d) (4). Rademacher et al (18) described a drop in mortality when the average weaning weight moved from 3.6 to 5.4 kg, but they did not report the weaning age of the groups. Fangman et al (1) concluded that a 5 kg average weaning weight for weaned pigs between 16 and 23 d of age would be a desired target.

Weaning weight variation may result in increased labor costs, complicated management, and lowered profitability (19). Thus, a weight threshold is a useful management tool to devise subgroup interventions (below the weight threshold), in the case of the availability of strategies to reduce the negative effect of lightweight at weaning on mortality or low ending weight, or, at least, for a more

Table 2. Univariate odds ratios for nursery barn mortality and risk of being lightweight at 10 wks of age

	Response variables					
	Mortality[a]			Lightweight at week 10 of age[b]		
Risk factor	Odds ratio	- + 95 %CI	*P*	Odds ratio	- + 95 % CI	*P*
Birth weight (≤ 1 kg vs > 1 kg)	1.91	1.15–3.16	0.01	3.25	2.34–4.51	0.0001
Weaning weight (≤ 3.6 kg vs > 3.6 kg)	2.98	1.83–4.85	0.0001	8.50	6.06–11.91	0.0001
Farrowing dam (gilt vs sow)	0.70	0.37–1.32	0.27	1.12	0.78–1.60	0.51
Cross fostering (yes vs no)	0.71	0.40–1.23	0.22	1.78	1.30–2.47	0.0004
Sow unit (A vs B)	2.01	1.23–3.28	0.004	1.29	1.75–0.94	0.11
Barrow (barow vs gilt)	1,92	3.22–1.17	0.009	1.51[c]	1.11–2.06	0.007
Weaning dam (gilt vs sow)	0.62	0.33–1.17	0.13	1.49	1.05–2.10	0.02
Weaning age (≤ 17 d vs > 17 d)	1.15	0.51–2.58	0.73	1.35	0.90–2.03	0.13
Barn (C versus D)	0.99	0.96–1.02	0.12	1.20	0.88–1.63	0.08

[a]n = 1010 pigs
[b]n = 939 pigs
[c]The odds ratio reported is for gilts vs barrow

Table 3. Factors associated with mortality and lightweight at week 10 for nursery pigs at a farm in Iowa, 2002

Response variable[b]	Risk factor[a]	Odds ratio	- + 95 % CI	*P*
Mortality	Weaning weight (≤ 3.6 kg vs > 3.6 kg)	2.92	1.87–4.56	0.0001
	Barrow (barrow vs gilt)	1.75	1.13–2.70	0.01
	Sow unit (A vs B)	2.14	1.01–4.56	0.04
	Weaning age (≤ 17 d vs > 17 d)	0.87	0.72–1.06	0.1706
Light weight at 10 wk of age[d]	Weaning weight (≤ 3.6 kg vs > 3.6 kg)	8.75	5.84–13.12	0.0001
	Birth weight (≤ 1 kg vs > 1 kg)	2.66	1.75–4.04	0.0001
	Gilt (gilt vs barrow)	1.40	0.96–2.04	0.07
	Sow unit (A vs B)	2.38	1.49–3.70	0.0002
	Gilt (gilt vs sow at weaning)[c]	1.66	1.08–2.56	0.01
	Weaning age (≤ 17 d vs > 17 d)	1.05	0.94–1.17	0.34

[a]Odds ratio effects are adjusted for remaining factors
[b]Both logistic models included litter as random effect (Glimmix macro; SAS)
[c]Parity of the nursing sow at weaning regardless of the cross fostering status
[d]Less than or equal to 14.5 kg

Table 4. Proportion of cases attributable to each factor for mortality and with lightweight at 10 wk of age (weaning age 17 ± 2 d)

Dependent variable	Risk factor	Cases[a]	PAF	+ - 95 % CI
Mortality	Weaning weight (≤ 3.6 kg vs > 3.6 kg)	0.27	0.18	0.13–0.21
	Barrow (barrow vs gilt)	0.53	0.24	0.36–0.07
	Sow unit (A vs B)	0.42	0.22	0.00–0.33
Light weight at 10 wk of age[c]	Weaning weight (≤ 3.6 kg vs > 3.6 kg)	0.54	0.48	0.45–0.50
	Birth weight (≤ 1 kg vs > 1 kg)	0.42	0.26	0.18–0.32
	Sow unit (A vs B)	0.37	0.21	0.12–0.27
	Gilt (gilt vs sow dam at weaning)[b]	0.60	0.24	0.05–0.37

PAF — Population attributable fraction
[a]Proportion of dead or lightweight pig with the characteristic
[b]Parity of the nursing sow at weaning regardless of the cross fostering status
[c]Less than or equal to 14.5 kg

intensive monitoring of that population segment. The weaning weight threshold can be subject to modifications; by being higher than 3.6 kg, more pigs will be included in the target population and more pigs at risk (of dying or being lightweight pigs) would be monitored closely. However, as the weight threshold increases, more pigs that are expected to have good performance (survival and heavyweight pigs) will also be subject to monitoring. That trade off suggests that maximizing both Se and Sp (weaning weight of 3.6 kg) may not be the best criterion under every situation.

There was no systematic collection of data on clinical signs during this study, but diarrhea and locomotory problems were commonly seen during the nursery period. The weaning transition is a stressful process (20) and factors present at weaning may have been involved in the lower survival observed within the 4 wk after weaning. However, the use of gender and weaning weight as predisposing factors still differentiated pigs with respect to their likelihood of survival. No data are available to compare our findings on the cumulative survival during the nursery phase with other populations. In addition, the mortality rate observed in this study was higher than the standard reported for North America (21).

Changes in the standard errors and the magnitude of the odds ratios were observed when litter was included as a random effect in the logistic model (22). The significant litter effect means that the mortality rate and the likelihood of being light at nursery exit differed from litter to litter due to characteristics not identified in the study. Evidence of litter effects (size, weight variation, and other dam attributes) have been reported as being a considerable source of variation for birth and weaning weight (23,24) and for growth performance during the nursery phase (7).

Dam parity and cross fostering have a minor effect on nursery pig survival. Birth weight was associated with nursery mortality, but its effect was nullified when weaning weight was considered in the model (Table 2). Heavier pigs at birth have more chances of survival and faster growth (24,25). Light weaning weight may have accounted for the effect of birth weight in the model, which was then redundant in explaining nursery mortality variation.

Studies have confirmed that compared with gilts, males have a slightly lower chance of survival before weaning (26). Such differences have been attributed in newborn pigs to higher testosterone (27) and cortisol levels in males (28). However, no explanation is available for such an effect on nursery mortality. So far, no strategies have been devised to mitigate the gender effect on mortality. The strong association of gender with mortality, even after the adjustment for weaning weight and farm, suggests its role as a potential confounder when population studies are conducted.

The 2 farrow-to-wean farms supplying pigs for this study were similar in many respects, although pigs from 1 source experienced a higher risk of dying, apart from the gender and weight effect. Birth weight was associated with low ending nursery weight (17 d to week 10) (Table 3). Our findings are consistent with results from investigations showing the effect of weaning weight on postweaning growth performance (2,4,29).

Wolter et al (30) reported that heavier pigs at birth (the heaviest 30% of the litter) had a greater average daily gain and feed intake than low birth weight pigs (the lightest 30% of the litter), but no differences between them were observed in the feed/gain ratio during the postweaning phase. Birth and weaning weight have an independent effect on weight at 10 wk of age, since they remained significant in the multivariate model without interacting each other. Under experimental conditions, birth weight has been shown to have a strong effect on nursery performance, even after the implementation of feeding strategies to increase piglet milk intake (30). This fact may challenge the opportunity to make an improvement, since the control of variation in birth weight may be limited. Still, weaning weight had an additional effect on the risk of being a lightweight pig at exit. This suggests that control of lightweight pigs at nursery exit should be focused on by reducing the negative effect of weaning weight and the proportion of lightweight pigs at weaning.

Continuous cross fostering (cross fostering permitted at anytime during the nursing phase), which is known to have a negative effect on preweaning growth (31), was practised on both farms. Cross fostering (Y versus N) was associated with lower weaning weight and was more likely to occur among low birth weight pigs (data not shown); it was also associated with weight at exit in the univariate analysis (Table 2). However, cross fostering was no longer associated with lightweight pig status at week 10, when birth and weaning weight categories were considered in the analysis. Therefore, cross fostering practices did not have direct implications on the light weight status at the end of the nursery phase (17 d to week 10).

Gender differences in growth are very well recognized in grow-finish pigs (32), with barrows growing faster than gilts. When variation from litter to litter was accounted for in the model as a random effect, the gender effect on the weight status at exit (10 wk old) was no longer significant. In this sense, previous research in nursery pigs has shown no differences in the growth rate between genders (7,33).

Since gilts produce less milk than older parity sows, the higher risk of being lightweight at exit observed on pigs nursed by gilts seemed plausible. However, the association must be interpreted with caution, because data on the time spent by the pig with the nursing sow, either the mother or the foster sow, were not collected; therefore, an adjustment in the analysis could not be made.

The population attributable fractions are not necessarily additive, because cases can be exposed to more than 1 risk factor simultaneously. Improvements in reducing the proportion of lightweight pigs at weaning (17 ± 2 d) can decrease nursery mortality, although most of the deaths in this population were due to unknown factors. Further investigation into the risk of dying, taking into account the weight and gender, should be considered. The reduction in the proportion of lightweight pigs at weaning (17 ± 2 d), or its effect on nursery performance, may have a high impact on the proportion of lightweight pigs at exit. Light weaning weight pigs, which were also younger, may be more immature regarding their digestive capabilities (28); as a consequence, their adaptation to the grain-based feed could have been delayed. This could partially explain the higher risk observed among the light weaning weight pigs. Changes in the complexity of the diet or the administration of milk replacers may help to reduce the negative effect of light weaning weight on growth (3,33).

Since this was a single system study, the extrapolation of the findings to other populations would certainly be difficult, unless consideration about the mortality rate, weaning weight and age (17 ± 2 d) distribution, and disease background in the herd are taken into account. In that context, the present findings have provided data that can help when strategies are being devised for categorical interventions when the improvement of weight at nursery exit or the reduction of mortality is the concern. The monitoring of weaning and birth weight, farm source, and pigs nursed by gilts was found to provide good prognostic indicators for identifying pigs with a higher risk of substandard nursery performance. Therefore, the criteria elaborated can be used to indicate which pigs would have higher propensity to fail in performance. CVJ

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