



Gilt birth weight, sow birth weight phenotype and sow fertility

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Introduction

Decades of selection for larger litter size has resulted in a reduction in average birth weight, an increase in number of small piglets and an increase of within-litter birth weight variation in pigs (Quiniou et al., 2002; Foxcroft et al., 2009; Matheson et al., 2018). These low birth weight offspring are a major concern for the swine industry and have significant negative impacts within pork production systems. In commercial pigs, low birth weight pigs have been shown to have increased mortality rates, slower growth and comprised carcass quality (Smit et al., 2013; Magnabosco et al., 2015; Moreira et al., 2017). In replacement females, in addition to the negative effects on growth, low birth weights have adverse impacts on reproductive performance and sow lifetime productivity (Foxcroft et al., 2009; Da Silva et al., 2016; Magnabosco et al., 2016; Patterson et al., 2020). The detrimental effects of low birth weight are not only restricted to small pigs within a litter, but also may extend to entire litters that are prenatally programmed to have a lower than average birth weight (low litter birth weight phenotype (BWP) and compromised postnatal growth performance (Foxcroft et al., 2009; Smit et al., 2013). Within a commercial multiplication program, this presents an additional risk, as the low litter BWP is a repeatable trait in a sow's productive life, and the sow passes these traits on to her progeny (Ladinig et al., 2014). This paper will discuss the recent results of a study completed as part of a national Pork Board-funded project to investigate links between individual birth weight, birth weight phenotype and their interaction on the efficiency of replacement gilt production at production nucleus-multiplication level and on the performance of gilts selected for breeding (see Patterson et al., 2020).

Low individual birth weight gilts

Within the current literature, there is consensus showing the risk of low birth weights on future growth and reproductive performance of replacement gilts. Gilts weighing less than 1.0 kilogram at birth have increased preweaning mortality rates and have little chance of surviving until weaning (Magnabosco et al., 2015). Those gilts that do survive past the nursery phase have poor growth until finishing and are significantly lighter than their higher birth weight litter mates (Magnabosco et al., 2015). Additionally, the future reproductive performance as replacement females is compromised in low birth weight gilts. Almeida et al. (2017) reported that low birth weight affects vaginal length and ovarian follicular dynamics at 150 days of age, potentially leading to poor future reproductive performance. Gilts weighing less than 1.0 kg at birth had fewer total pigs born alive at first farrowing, fewer pigs produced over three parities and increased removal due to anestrus, compared to gilts weighing over 1.0 kg (Magnabosco et al., 2016).

Low birth weight phenotype sows

A sow "low litter birth weight" phenotype at nucleus and multiplication level carries all the same risks described above for individual low birth weight gilts but as a repeatable "litter" trait (Smit et al., 2013; Patterson et al., 2020). A negative relationship between total born (litter size) and litter average birth weight (average of all pigs in the litter) exists (Figure 1). Over the entire population of litters shown, total litter size explains part of the difference in litter average birth weight ($R^2 > 0.13$), representing a 600-gram difference between the smallest and largest litters. In contrast, the variation in litter average birth weight among litters with the same total born was greater (mean = 1,350 grams, range 900 to 1,700 grams). As litter size increases, there is an increasing lack of high birth weight litters due to increased prolificacy. As shown in Figure 1, the litter average birth weight of the most prolific sows with more than 20 total born are lower than the population average litter birth weight of around 1.35 kilograms. In contrast to these effects of increasing prolificacy on the upper range of litter average birth weights, across the entire range of litter sizes from ten to more than 20 pigs total born, there is a population of

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approximately 10-15% of sows that repeatedly have low birth weight litters that cannot be attributed to prolificacy in the sense of total pigs born.

This trait is repeatable over consecutive parities in terminal-line sows and arises from interactions among the component traits of ovulation rate and the dynamics of early embryonic survival, which in turn lead to excessive intrauterine crowding in early gestation and limited placental development (Foxcroft et al., 2009; Smit et al., 2013; Ladinig et al., 2014; Da Silva et al., 2018). More recently, Moroni (2020) determined that the primary driver of impaired embryonic development and lower average weight in sows with the low litter BWP is due to limited uterine capacity and lower placental efficiency leading to an unfavorable intrauterine environment at day 30 of gestation. Later in gestation, a low BWP is associated with characteristics of intrauterine growth retardation (IUGR) independent of the size of the litter born (Smit et al., 2013). As suggested by Matheson et al. (2018), IUGR is part of a foetal adaptive reaction to placental or nutritional insufficiency and will have permanent effects on future production. Selecting for increased overall prolificacy appears to have indirectly created an imbalance in a subpopulation of sows between the numbers of developing embryos in utero and functional uterine capacity to support the optimal development of surviving fetuses to term.

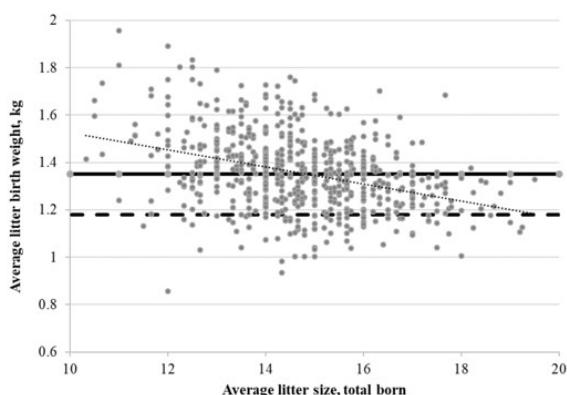


Figure 1. Relationship between litter size (as total number of pigs born) and litter average birth weight in 644 sows. The average litter birth weight over the population is 1.35 kg (solid black line). The dashed black line indicates the birth weight of 1.18 kg, below which sows were classified as having a low birthweight phenotype. *From: Journal of Animal Science. 98. doi:10.1093/jas/skaa331*

Individual birth weight, sow birth weight phenotype and their interaction

Our recent study investigated the relationship between individual birth weight, birth weight phenotype and their interaction on the efficiency of replacement gilt production at production nucleus-multiplication level. Sows were classified by their mean litter average birth weight ($n = 644$: overall mean litter average birth weight = 1.35 kg) over at least 2 parities into three sow BWPs with respect to the critical threshold of birth weight for increased mortality established (1.18 kg) as follows: low BWP (L-BWP: < 1.18 kg; $n = 85$); medium BWP (M-BWP: ≥ 1.18 to ≤ 1.35 kg; $n = 250$), and high BWP (H-BWP: > 1.35 kg; $n = 309$). Our goal was to determine the effect of a repeatable sow BWP on the efficiency of replacement gilt production at production nucleus-multiplication level. Proven gilt development protocols for final gilt selection involving both direct and fence-line contact daily with mature boars in a purpose designed facility were a critical component in this study (Patterson et al., 2016). Key components for gilt eligibility at service included age at puberty (<200 days of age), and weight (135-160 kg) and estrus at service ($\geq 2^{\text{nd}}$ estrus) were implemented (Patterson and Foxcroft, 2019).

In our study, we investigated the effects of individual birthweight (BWi) of gilt, sow BWP, and their interactions on gilt performance as measured by the following key components of an efficient gilt development program:

Selection Efficiency.

Low individual birth weight is a primary concern for early losses of potential replacement gilts. Individual gilts weighing less than 1.18 kilogram at birth have increased preweaning mortality rates with 4 days of birth (Figure 2). Sow birth weight phenotype is also a significant risk factor for low retention of

gilt progeny until selection as nearly 60% of all pigs born to these sows have an individual birth weight less than 1.18kg.

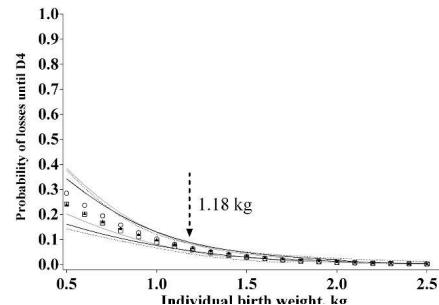


Figure 2. Predicted probabilities of mortality and losses until 4 d of age by individual birth weight (BWi) and birth weight phenotype (BWP) estimated using logistic regression models. L-BWP: piglets with an individual birth weight < 1.18 kg; M-BWP: piglets with an individual birth weight ≥ 1.18 to ≤ 1.35 kg; H-BWP: piglets with an individual birth weight > 1.35 kg. The dashed arrow indicates the best cut-off point of BWi for survival until 4 d of age. Solid black line, solid gray line and dotted black line indicate the 95% confidence limits for H-, M- and L-BWP, respectively. From: *Journal of Animal Science*. 98. doi:10.1093/jas/skaa331

Growth Potential

Low individual birth weight is positively linked to postnatal growth until pre-selection at 160 days of age. Furthermore sow BWP is also an important factor, gilts <1.18 kg and born to sows with the L-BWP have slower growth rates compared to M- and H-BWP sows. This is not surprising as gilts born to L-BWP dams would have limited developmental and growth potential as the result of IUGR. Lower growth rates may delay the attainment of puberty, and achieving a minimum body weight or a particular metabolic state may also be prerequisites for puberty to occur (Beltranena et al., 1991; Patterson et al., 2020). The lower birth weight and slower growing gilts in the present study may not have met these thresholds. In contrast, those gilts born to H-BWP sows and with growth rates of greater 700 g/d may be at risk for exceeding the target ranges for weight at service at second estrus.

Responses to puberty induction in the gilt development unit

Low individual birth weight affected the response to puberty induction stimuli. As discussed above, puberty is delayed in lower birth weight and slower growing gilts. Gilts with a birth weight less than 1.20 kg showed a delayed response to puberty stimulation after 21 days of intensive boar contact (Figure 3a). However, most gilts still have adequate growth for achieving sexual maturity (> 0.55 kg/d) after 35 days of puberty stimulation (Figure 3b). When gilts continue to be stimulated and monitored for longer periods (up to 260 days of age), most will eventually have a recorded estrus (Calderón Díaz et al., 2015). Therefore, with effective GDU program in place, >80% of gilts had a recorded estrus within 35 days (Figure 3b).

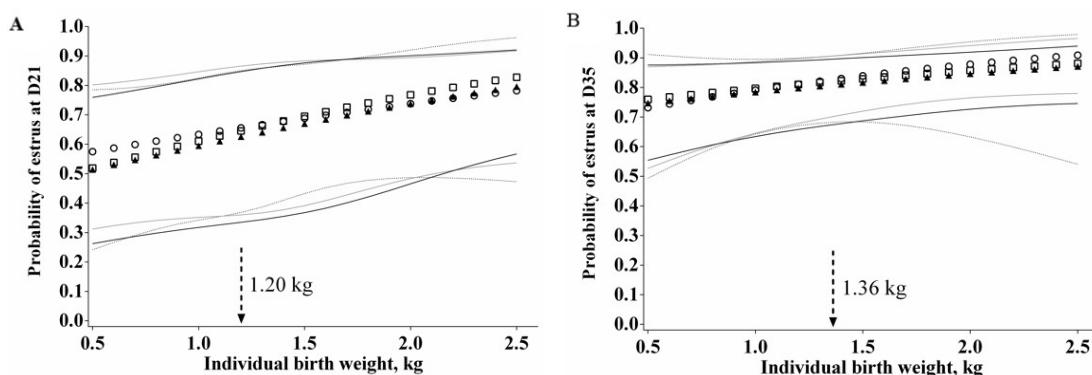


Figure 3. Predicted probabilities of attaining puberty by 21 (A) and 35 d (B) after the initiation of boar exposure according to individual birth weight (BWi) and birth weight phenotype (BWP), estimated using logistic regression models. L-BWP: piglets with an individual birth weight < 1.18 kg; M-BWP: piglets with an individual birth weight ≥ 1.18 to ≤ 1.35 kg; H-BWP: piglets with an individual birth weight > 1.35 kg. Dashed arrows indicate the best cut-off points of BWi for puberty attainment. Solid black line, solid gray line and dotted black line indicate the 95%



confidence limits for H-, M- and L-BWP, respectively. *From: Journal of Animal Science.* 98. doi:10.1093/jas/skaa331

Post selection performance and retention in the breeding herd.

Generally, we reported a lack of effect of litter of origin on litter size in the population of select gilts that entered the breeding herd. A trend for increased stillborns in parity 1 in H-BWP gilts was detected, which may reflect the reported risk of stillborns in gilts with higher growth rates or excessive body weights (Amaral Filha et al., 2008; Bortolozzo et al., 2009; Faccin et al., 2017). Additionally, second litter size was compromised in gilts from H-BWP dams compared to M-BWP dams, and increased catabolism during lactation may be a related factor (Patterson et al., 2020). Although, industry benchmarks of greater than 70% of gilts retained to third parity were met, gilts born to sows with the H-BWP tended to have a higher rate of attrition over successive parities.

Conclusions

The overall efficiency of a gilt development program, particularly poor survival to weaning, and lower gilt retention rates during development, is negatively impacted by low birth weight gilts and for those gilts born to sows with a low BWP. Generally, L-BWP sows represented the 10 to 15 % of sows producing litters with the greatest risk of increased death in the immediate postnatal period and many of these gilts born (58% with individual birth weights <1.18 kg) are at risk for poor growth and retention. Sows with a repeatable low BWP at the level of the production nucleus will decrease the efficiency of the genetic transfer program, decrease the number of select gilts per sow bred and increase the proportion of low birth weight gilts born. As previously concluded by Foxcroft and Patterson (2020), retaining low BWP sows in the production genetic nucleus population impacts the efficiency of replacement gilt production and represents a poor return on the investment in their high genetic merit. Nucleus sow culling strategies aimed at the early removal of the 10 to 15% of sows with the extreme low BWP, as well as non-selection at birth of the lower birth weight gilts from other litters, will improve the overall efficiency of the nucleus/multiplication farm in terms of efficient genetic transfer. Additionally, implementation of an efficient gilt development program is an essential component of sow lifetime productivity.

Disclosure

This paper is based on earlier reviews and scientific articles presented by both authors, as cited in the references included.

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