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Possible physiological benchmarks for sow longevity prior to puberty

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Introduction

High replacement rates for P1 and P2 sows have skewed parity distributions on most North American breeding farms towards younger females. As a result, overall herd productivity is being limited because females are being culled before they reach their peak periods of reproductive performance. There is no question that management conditions to which sows are exposed have significant impacts on their retention in the breeding herd. Weaning-to-estrus intervals, ovulation rates and the successful establishment and maintenance of pregnancy can either be enhanced or suppressed by a variety of factors including nutrition, temperature, housing conditions and social interactions (Flowers, 1999). From a physiological perspective, this can be thought of as the functional period of reproductive management because it is a reflection of how well the reproductive organs of sows function to produce live piglets within their production environment. In most situations, management mistakes during the functional phase are correctable. For example, if excessive loss of body condition occurs during lactation due to poor feed intake, then it can be replenished subsequently with the appropriate feeding regimens.

Management conditions to which gilts are subjected to pre- and postnatally also have important and lasting effects on their reproductive performance as adults. This is not surprising since key developmental events begin during the latter portion of pregnancy and aren't completed until 90 days after birth. These lay the foundation for how well the brain and other reproductive organs will communicate with one another during the functional phase of their reproductive life (Pressing et al., 1992; Morbeck et al., 1993). This can be thought of as the development period of reproductive efficiency (Figure 1). In contrast, mismanagement during the developmental period most likely introduces permanent reproductive inefficiencies that will be difficult to reverse later during the functional phase.

From a practical perspective, sow longevity issues can arise from problems females encounter during the developmental phase, the functional phase, or both. At the present time, no definitive physiological benchmarks are available for producers to use to assess how well their reproductive system (and longevity potential) develops during puberty. These, if they exist, are essential for the creation of management programs that will optimize sow longevity. The primary purpose of this paper is to investigate the relative potential that several prepubertal events have as possible physiological markers for sow longevity.

Birth weights

The ovaries, uterus, and portions of the brain involved with the production of reproductive hormones can be visualized in developing fetuses by day 50 of gestation. Throughout the remainder of pregnancy, these organs increase in size, so by birth, they have the majority of the basic cell types that they will use as sows. Thus, at least anatomically, the majority of the framework for the sow's subsequent reproductive potential appears to be in place when she is born. Consequently, the first potential physiological benchmark for reproductive potential that producers have the opportunity to evaluate is birth weight. There are well-established, positive relationships between birth weight and the size of most internal organs including the brain, intestines, liver, and the number of fibers in some skeletal muscles (Gondret et al., 2005; Foxcroft et al., 2009). There is no reason to think that this relationship does not also hold true for the ovaries, uteri, and reproductive centers of the brain – as birth weight increases so does the size and development of these organs. In fact, previous studies that internal ograns collected from stillborn piglets weighing less than 1.5 lbs and "runts" that were born alive but died shortly after clearly show severe retardation of the ovaries and uteri.

Information about relationships between birth weights and lifetime productivity currently is being evaluated by several different groups. Preliminary data from several of these studies are encouraging. Data from one of these studies is shown in Table 1. These data were collected within the multiplication phase of a small production system in which it was customary to "over breed" replacement gilts. After pregnancy diagnosis at day 28 surplus pregnant gilts were marketed, which allowed for the evaluation of some important reproductive characteristics. While these data are based on only about 75 gilts in each of the weight

Figure 1: Schematic time line for physiological events that influence sow longevity.

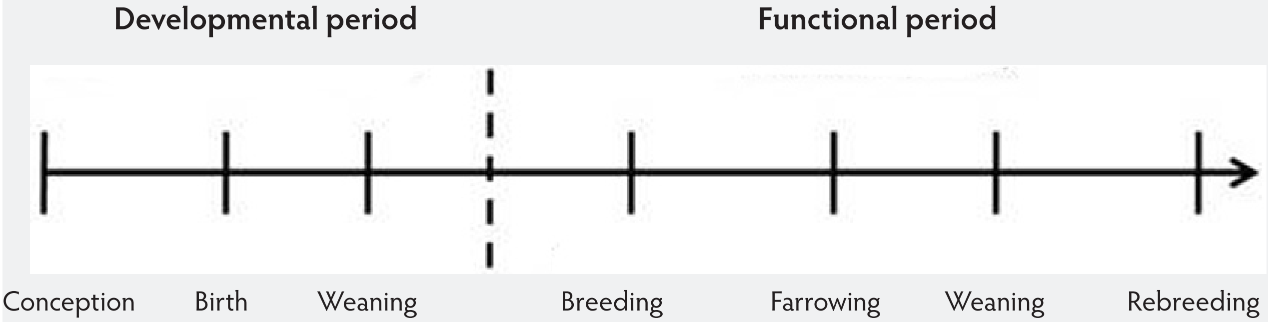

Table 1: Birth weights of replacement gilts and their relationship to puberty, ovulation rate and early embryonic survival. (Flowers, unpublished)

Reproductive	Piglet birth weights (lbs)	
Performance	**≥ 3.5 lbs**	**2.0 – 2.8 lbs**
Age at puberty (days)	170 ± 8	188 ± 6
Ovulation rate	15.3 ± 0.7	12.9 ± 0.6
Embryonic survival (%)	83 ± 6	69 ± 7

classes, they do show a positive trend between birth weight and reproductive performance early in the first pregnancy – the largest gilts at birth exhibited a tendency to perform better compared with their smaller counterparts. What is interesting to note is that if no other reproductive losses occurred in each of these groups of females, then the ones with the heavy birth weights would be expected to produce around 12 total pigs (15 ovulations × 83% survival), whereas those with light birth weights should farrow around 9 (13 ovulations × 69%).

These data are preliminary, but they do seem to support the notion that birth weights may have some association with subsequent reproductive potential. It is reasonable to speculate that there probably is some minimum birth weight, below which gilts simply do not have the reproductive machinery to produce large numbers of piglets consistently for 6 or more parities. Moreover, it is also reasonable to speculate that the minimum threshold could vary among production systems. Ultimately, it will be up to producers to determine the relationships between birth weight and subsequent reproductive potential within their own systems. One way to accomplish this would be to record birth weights on all potential replacement gilts and then, after they enter production, retrospectively determine if and to what degree they are associated with sow longevity.

Pre-weaning growth

Birth weight primarily is a function of total pigs born - as the total number of pigs born increases, the average birth weight decreases and becomes more variable. As a result, it can be thought of as a reactive benchmark or variable - it is something that producers have very little control over and must react to once pigs are born. Nevertheless, producers may have an opportunity to correct some potential deficiencies during prenatal development postnataly. The concept that the litter size in which a replacement gilt nurses influences her performance as an adult is not new (Mavrogenis and Robison, 1976). The positive attributes of being raised in a small litter that were reported over 30 years ago were linked to pre-weaning growth. When this original work was done lactation lengths in excess of 35 days were common and gilts from large litters most likely were exposed to a mild form of growth restriction as their weaning weights were considerably lighter compared with females that were allowed to nurse in small litters. An obvious question is whether this phenomenon still has relevance for modern production systems using hyperprolific, maternal-line genetics and much shorter lactation lengths.

A recent study conducted in a modern commercial production system indicates that it does. In this study, replacement gilts born in litters of 10 to 12 piglets were cross-fostered so that they nursed in litters of less than 7 or greater than 10 piglets. After weaning, the females from the small and large lactation litters were sent to commercial farms and managed under the same conditions. At the end of 6 parities 18% more sows raised in small litters were still in production compared with their counterparts from large litters. In addition, sows that nursed in small litters had higher farrowing rates and tended to have more born alive compared with sows weaned from large litters. One interpretation of these results is that reducing competition during the neonatal period enhanced both the structural and functional development of the future replacement gilt's reproductive organs. This, in turn, could have created a situation in which the entire reproductive axis operated more efficiently during its functional phase. Ovarian and neural development continue after birth so it physiologically reasonable to see how this might occur.

One of the intriguing aspects of this study which deserves further exploration is the possible interaction between birth weight the neonatal environment. The average birth weight of all the replacement gilts in this study was 2.8 lbs. As mentioned earlier, a significant, positive relationship between birth weight and the development of internal organs and muscle fibers exists for market animals – those with light birth weights had fewer muscle fibers per bundle and less developed livers and intestines (Gondret et al., 2005). As a result, they grew slower; reached market weights later; and had lower percent muscle compared with their counterparts with heavy birth weights. This phenomenon is referred to as intrauterine growth retardation and may have important implications for replacement gilts that are from highly prolific maternal sow lines. The tendency would be for them to have reduced birth weights and perhaps reduced developmental potential due to being born in large litters. A retrospective analysis of the influence of birth weight within each lactational litter size is shown in Table 2.

It is important to remember that only litters with 10 to 12 pigs born alive were selected in an attempt to minimize any inherent differences in birth weights. As a result, the proportion of very light and heavy birth weights is small. Nevertheless, the size of the litter in which replacement gilts nursed had minimal influence on her longevity if her birth weight was greater than 3.6 lbs. In contrast, for those with lighter weights, longevity was more than doubled when they were allowed to nurse in small litters. One explanation for these results is that, in this particular system, replacement gilts weighing 3.5 lbs or less at birth may have been subjected to some degree of intrauterine growth retardation. Reduction of the litter size in which they nursed allowed them to compensate for some of this prenatal restriction after they were born with the end result being increased longevity.

In terms of a physiological benchmark that producers could use to evaluate this phenomenon, expressing a gilt's preweaning growth as a percentage of her weaning weight may prove to be the most useful. The best way to illustrate this is to consider the following example – two gilts are born and weigh 2 and 4 lbs, respectively, but both gained 14 lbs during lactation. In this scenario, the 2-lb gilt achieved 87.5% of her weaning weight (14 lbs preweaning growth/16 lbs weaning weight), while the preweaning growth of the 4-lb pig accounted for 77.7% of her weaning weight (14 lbs preweaning growth/18 lbs weaning weight). While both have the same pre-weaning growth and the one with the birth weight of 4 lbs has the heavier birth weight, the 2-lb gilt actually achieved a higher percentage of her weaning weight due to preweaning growth than her 4-lb counterpart. When relationships among birth weight, weaning weight, pre-weaning growth and the proportion of the weaning weight due preweaning growth were evaluated using multiple regression techniques, expressing preweaning growth as a proportion of weaning weight explained the largest proportion of the variation observed in most measures of sow longevity in the study mentioned previously. From a practical perspective what this means is that preweaning growth relative to a gilt's birth weight was the best predictor of her longevity potential in this particular study. Clearly, additional work is needed in this area to confirm and extend these observations, but collecting birth and weaning weights and estimating preweaning growth appears to hold merit for multiplication systems for replacements gilts.

Table 2: Interactions between neonatal litter size and birth weight on the proportion of sows farrowing 6 or more litters (Flowers, in press).

	Birth weight categories		
Neonatal treatment	**≤ 2.5 lbs**	**2.6 – 3.5 lbs**	**≥ 3.6 lbs**
≥ 10 piglets nursing	10.4% (10/96)	15.8% (115/727)	32.4% (32/98)
≤ 7 piglets nursing	26.2% (26/99)	39.1% (274/701)	36.3% (36/99)

Physiological responses associated with boar exposure and puberty

The culmination of the developmental period for gilts is whether they can exhibit estrus and ovulate in response to boar exposure. Arguably, this is the best physiological benchmark that the hormone-producing centers of the brain and the ovaries can function as they will need to do during the functional phase. There is considerable evidence that females that respond early to boar exposure have greater longevity and productivity as sows compared with those that do not. This seems to be true regardless of when they are bred relative to the expression of their first estrus. In essence, the ability of gilts to respond early to boar exposure might be the best way to assess how well they have been managed during the developmental period and their subsequent longevity potential.

Unfortunately, early boar exposure presents a number of logistical and biosecurity challenges for most producers. First, in order to critically identify early responders, boar exposure needs to begin when replacement gilts are around 140 to 150 days of age which in most production systems is prior their arrival at commercial sow farms. Second, most systems would prefer to delay first mating in order to allow for maturation of other physiological aspects associated with replacement gilts. This creates a situation in which the synchronization of the puberal estrus that normally can be achieved when boar exposure is delayed is essentially lost. Finally, introduction of mature boars for the purpose of puberty induction in multiplication barns compromises biosecurity. Development of way to test the responsiveness of replacement gilts without the physical presence of a boar and without actually inducing ovulation would be attractive to many production systems. They could obtain information about sow longevity; still maintain strict biosecurity; and realize the advantages of delaying boar exposure in terms of synchronizing the pubertal estrus.

Such a test might be possible if some behavioral responses associated with estrus could be uncoupled from their physiological companions. The entire physiology associated with estrus is a bioassay for circulating levels of estrogens. Reddening and swelling of the vulva occur first when levels begin to increase above baseline values. This is followed by the standing reflex as concentrations increase even more and, ovulation eventually results when levels reach the threshold necessary to induce the pre-ovulatory surge of gonadotropins. Based on this physiological sequence, it theoretically should be possible to create a situation in which the reproductive axis of the gilts is stimulated just to produce just enough estrogen to cause swelling of the external genitalia, but not enough to cause the standing reflex or ovulation.

One approach that is currently being investigated involves the use of low levels of commercially available gonadotropins administered to gilts between 140 to 150 days of age and evaluation of their subsequent physiological responses. The initial responses to this strategy appear promising. There was variation in both the intensity of the reddening and swelling of the vulva and the time course over which it occurred. None of the gilts exhibited a standing reflex and real-time ultrasonography revealed no ovulations had occurred in any of the gilts by 28 days post injection. Figure 2 illustrates the time course over which changes in the vulva occurred in response to low doses of gonadotropins (top panel) and compares it with a group of their contemporaries that were given boar exposure at 140 days of age (bottom panel).

Whether or not these gonadotropin-induced changes are related to sow longevity is currently being evaluated. However, if successful, then could be developed into a useful and flexible tool with a number of potential applications. Some producers might decide to use it as part of their selection criteria for saving replacement gilts – only ones that respond by a certain time are kept as replacement females. In this scenario, identification of positive responders at a young age would coincide with the normal market ages and weights for most farms. Those that do not exhibit a positive response could be sold as market animals without significant discounts. Others might decide to test only a subset of their gilts periodically to assess the appropriateness of their management systems for replacement females from birth to the point in time when the test is administered. For example, if 80% of the group tested responds with rapid, intense changes in the external genitalia, then gilt development programs might be deemed as acceptable, whereas if only 20% test positive, then changes in management conditions early in their lives might be necessary. This information would be extremely useful in helping producers "trouble-shoot" sow longevity problems or simply develop strategies to make a good management program better.

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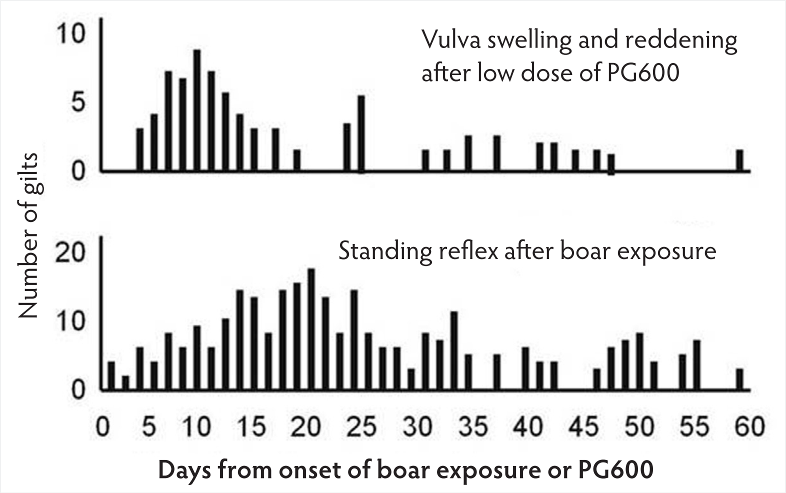
Figure 2: Variation in response of 150-day old gilts to either low doses of gonadotropins (top panel) or boar exposure (bottom panel) (Flowers, unpublished observations).



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