Novel Insight into the Control of Litter Size in Pigs, Using Placental Efficiency as a Selection Tool

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ABSTRACT: Chinese Meishan pigs produce three to five more pigs per litter than less-prolific U.S. or European pig breeds as a result of a markedly decreased placental size and an increased pig weight: placental weight ratio (placental efficiency). We hypothesized that as a result of their intense selection for prolificacy, the Chinese had indirectly selected for a smaller, more efficient placenta in the Meishan breed. The goals of this study were to determine whether 1) significant variation in placental size and efficiency existed within our population of purebred Yorkshire pigs and 2) selection of pigs (boars and gilts) based on clear differences in placental size and efficiency would affect litter size. There was significant (approximately threefold) variation in placental efficiency in our herd of Yorkshire pigs, and marked (approximately twofold) variation existed within individual litters. We then selected pigs (boars and gilts) that had either a higher (A Group) or lower (B Group) than average placental efficiency. Although the birth weights of selected A Group pigs were similar to those of the B Group pigs, they had markedly smaller placentae. Males from each group (A or B) were bred to the females of the same group, and farrowing data were collected from parities 1 and 2. In both parities, A Group females farrowed more live pigs per litter than did B Group females (12.5 ± .7 vs 9.6 ± .5, P < .05). Although A Group pigs were on average approximately 20% lighter than B group pigs (1.2 ± .1 vs 1.5 ± .1 kg, P < .05), their placentae were approximately 40% lighter (250 ± 10 vs 347 ± 15 g, P < .01), resulting in a marked increase in placental efficiency. The results of this study suggest that selection on placental size and efficiency may provide a valuable tool for optimizing litter size in commercially important pig breeds.

Key Words: Pigs, Litter Size, Placenta


Introduction

We and others have investigated the physiological basis for the greater prolificity (three to five more pigs/litter) of Chinese Meishan pigs compared with U.S. or European pig breeds (Sellier and Legault, 1986). The tremendous asynchrony of development of littermates during the preimplantation period seems largely responsible for the high rate of embryonal loss (30 to 40%) in U.S. and European pig breeds (Dziuk, 1987; Pope, 1994). Before this period of significant loss, pig embryos grow very rapidly and initiate synthesis and secretion of estradiol-17β (E2β). The E2β from the most advanced embryos in a litter may alter the uterine environment to the detriment of the less-developed littermate embryos (Anderson, 1978; Pope, 1994). Meishan conceptuses have reduced trophoderm mitotic rates during preimplantation development, produce less E2β, are shorter after elongation, and have smaller placenta than conceptuses of U.S. or European breeds (Ashworth et al., 1988; Rivera et al., 1997; Wilson and Ford, 1997; Biensen et al., 1998; Wilson et al., 1998). We hypothesize that the slower growth rate and decreased E2β secretion of littermate preimplantation Meishan embryos allows more conceptuses to survive the early period of embryonal loss (i.e., d 12 to 18). The decreased placental size of Meishan conceptuses later in gestation allows Meishan sows to accommodate more conceptuses in uterine space similar to that in less prolific breeds (Bazer et al., 1988). The decreased placental size for Meishan conceptuses is associated with increased density of blood vessels in the outer...
placental membranes; this seems to meet the demands of the rapidly growing fetus during late gestation (Biensen et al., 1998).

If placental size and efficiency are heritable, one ought to be able to affect the number of viable pigs a female could carry to term. Thus, our objective was to determine whether there was significant variation in placental weight and efficiency for Yorkshire conceptuses.

Materials and Methods

Animals and Methods

In order to match individual pigs with their placentae, we observed eight straightbred Yorkshire sows immediately prior to and throughout farrowing. As each pig was farrowed, its umbilical cord was clamped next to the pig with an umbilical clamp (Hollister Umbilical Clamps, Libertyville, IL), and the most distal end of the umbilical cord visible at the vulva was immobilized with a pair of large curved hemostats. A numbered tag was attached by a length of silk suture (to match the birth order of the pig) to the umbilical cord, which was then cut, unclamped, and allowed to retract into the birth canal (Figure 1). Each pig was then identified by ear notching. The sows were continuously monitored until all the placentae were expelled, and the pigs and placentae were then weighed. Placental size and weight are highly correlated (Biensen et al., 1998), so we used the ratio of pig weight: placental weight (grams: gram) as a measure of placental efficiency.

From the progeny of the eight sows, with an average pig weight:placental weight ratio of 4.2 ± .2, 12 gilts and four boars were selected. Six gilts and two boars with above-average pig weight:placental weight ratios (5.7 ± .3; termed the A Group) and six gilts and two boars with below-average pig weight:placental weight ratios (3.6 ± .2; termed the B Group) were selected. At 7 mo of age, gilts from each group (A or B) were randomly bred to one of the two boars from the same group and monitored during farrowing to determine offspring pig weight:placental weight ratios. The sows in each group were then rebred to the same boar used during their first parity, and they were again monitored during farrowing with similar offspring data recorded.

Statistical Analysis

Data were analyzed using the GLM procedure of SAS (1985). The selected females were used as the experimental units for analysis, because pig weights, placental weights, and pig weight:placental weight ratios were averaged within a litter, and a single value for each litter was used in the analysis. The model included group, parity, and the group × parity interaction. The Correlation (CORR) procedure of SAS was used to analyze the relationship between average placental weight within a litter with the number of pigs in the litter both within and across groups. The results are presented as means ± SEM. For comparison, the mean ± SEM of pig weights and placental weights within each litter is presented.

Results

The pig weight:placental weight ratios for the offspring of the eight litters averaged 4.2 ± .2. Across the litters, individual pig weight:placental weight ratios ranged from 2.7 to 7.4. More importantly, within a given litter the pig weight:placental weight ratios ranged from 3.8 to 7.4. There was no difference in the birth weight of pigs selected to compose either the A Group or B Group (Figure 2). However, there was a marked difference (P < .01) in the weight of the placentae for these pigs; individuals selected for the A group developed on placentae ≈ 30% lighter than individuals selected for the B group. The lack of a group difference in pig weight and the marked group difference in placental weight accounted for the marked difference (P < .001) in relative placental efficiency (Figure 2). For the litters farrowed within each group (A or B), there was no difference (P > .40) in pig weight, placental weight, pig weight:placental weight ratio, or litter size between parities one and
Figure 2. Pig weight, placental weight, and the pig weight:placental weight ratio for individuals selected to establish the A and B groups. Means ± SEM with different superscripts within a measure differ (P < .05).

two. Therefore, data are presented as overall means across parity.

The weight of pigs farrowed in the A group (high ratio) was less (22%, P < .05) than that of pigs farrowed in the B group (low ratio) (Figures 3 and 4). More striking, however, was the marked difference (P < .01) in placental weight: pigs in the A group developed on placentae 39% smaller than those in the B group (Figures 3, 5). In addition to (and potentially a result of) the marked difference in placental size between the groups, there was a concomitant increase (P < .05) in litter size of nearly three pigs per litter for sows in the A group compared with those in the B group (Figure 3). In a contemporary unselected control population, litter size averaged 11.2 ± 0.5, intermediate between the A and B groups. Although there was an overall negative correlation (r = −.73, P < .01) between the average placental weight within a litter and litter size, within each group (A or B) the variation in average placental weight within a litter was not related to litter size (P > .20; Figure 6).

Figure 3. Pig weight, placental weight, and the litter size for the offspring of the A and B individuals over parities 1 and 2. Means ± SEM with different superscripts within a measure differ (P < .05).

Discussion

We have known since the early 1900s that total prenatal loss in U.S. pig breeds is between 30 and 40%, of which greater than 75% occurs before d 30 of gestation (reviewed in Pope, 1994). On or about d 12 of gestation, pig embryos undergo a tremendous morphological change from a 10-mm sphere to a 1-m-long filament within a 24-h period, referred to as elongation (Anderson, 1978; Geisert et al., 1982b; Pusateri et al., 1990). At the same time the embryo is preparing to undergo this rapid morphological change, it begins synthesizing and secreting significant quantities of E2β (Perry et al., 1973; Ford et al., 1982; Geisert et al., 1990; Pusateri et al., 1990). Embryonic E2β secretion induces marked changes in endometrial
given region of China (Epstein, 1969). Farmers in the Taihu region, experience a mild climate and have been selecting pigs for thousands of years for their prolificacy (Peilieu, 1985; Mao, 1995). Meishan pigs, one of the varieties included in the Taihu breed, give birth to three to five more pigs per litter than our high-producing U. S. pig breeds such as Yorkshire, even at ages when the two breeds exhibit similar ovulation rates and uterine sizes (Bazer et al., 1988; Christenson, 1993; Biensen et al., 1998). Because the ovulation rate of U. S. pig breeds averages ≈ 14 to 16 ova (Christenson, 1993), and litter size averages ≈ 10 pigs per litter (Pope, 1994), additional ovulations would not be expected to increase litter size. Selection for increased ovulation rate has been very successful (Lamberson et al., 1991). However, the increases in ovulation rate did not result in increases in litter size beyond the average for U. S. pig breeds (Neal et al., 1989).

Historically, uterine capacity has been simply defined as the number of conceptuses a female could carry to term (Christenson et al., 1987). In devising selection schemes to increase uterine capacity, one would think of increasing uterine horn length. However, selection for increased uterine horn length is complicated by the lack of information about the appropriate reproductive state during which to measure uterine length in order to appropriately quantify the phenotype. The importance of uterine capacity may result from the noninvasive, epithelial-chorial type of placentation found in this species (Grosser, 1933). Unlike rodent or human conceptuses, which invade into the endometrium during implantation, pig conceptuses do not erode maternal tissue and gain better access to nutrients in maternal blood, resulting in the need for a very large surface area for maternal-fetal exchange per unit of fetal weight (Friess et al., 1980). To accommodate this noninvasive placental type, the entire placental surface adjacent to the endometrium is highly vascularized. In an effort to select for uterine capacity, Christenson et al. (1987) employed a unilaterally hysterectomized-ovariectomized (UHO) model. Due to ovarian hypertrophy, a UHO female ovulates similar numbers of ova from the remaining ovary as would an intact female, with approximately one-half the uterine space (Dziuk, 1968). By selecting daughters of UHO females exhibiting the largest litter size, one would expect to be selecting for an increased uterine capacity (i.e., the number of conceptuses a female could accommodate to term). Unfortunately, the heritability of uterine capacity, as measured with the UHO model, is very low (.09, Young et al., 1996). We would like to propose that uterine capacity is better described as the total amount of placental mass or surface area a female can carry to term. This includes the absolute surface area available, and the efficiency of both endometrial and placental efficiency. Based on this notion of uterine capacity, litter size should be increased either by increasing uterine horn length or by decreasing the amount of the limited uterine space occupied by each conceptus. Our results suggest that placental efficiency is more important for influencing

![Figure 6. Average within-litter placental weight vs litter size for litters born to A and B group individuals.](image)
litter size. As a result of the inherent problems associated with selection for uterine length, we believe that selection for smaller, more efficient placentae is the better method. We are currently examining the impact of selection for placentation efficiency in a commercial seedstock herd.

**Implications**

Based on the current understanding of Chinese Meishan pigs, selection of pigs for smaller and relatively more efficient placentae seems to provide a useful method for increasing litter size in pigs. Such a selection method is simple and available to producers interested in increasing the prolificacy of their herd, or to seedstock companies interested in increasing the reproductive performance of their females.

**Literature Cited**


