Selection for Litter Size by Using the Ratio of Piglet Weight: Placental Weight as a Measure of Placental Efficiency

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Summary and Implications

The Chinese have been selectively breeding pigs for 7,000 to 10,000 years for increased numbers of pigs born, regardless of birth weight, indirectly resulting in the optimization of placental size and vascularity. In the United States, pig producers have generally selected for larger piglets at birth, resulting in a marked variation in placental size and vascularity. This tremendous variation in placental size and vascularity present within a litter may be ultimately limiting litter size. Therefore, by selecting against the large relatively avascular placentae, the potential for dramatically increasing litter size exists.

Introduction

The United States swine industry continues to be interested in and is actively attempting to increase the number of pigs born per litter. It has been estimated that an increase of one in the number of pigs born alive per litter would be worth nearly $2 billion to the United States swine industry. In the past, however, selection criteria for increasing litter size have included either the very lowly heritable trait of number of pigs born alive, or some candidate trait or gene believed to be closely associated with litter size (i.e., number of ovulations or estrogen receptor mutations). However, several lines of research have suggested that the major limitation to increasing litter size is a relatively fixed uterine capacity. The average ovulation rate is 14 to 16, of which greater than 95% are fertilized and yet average litter size in Iowa in 1996 was 9.7 pigs per litter. The importance of uterine capacity limitations is emphasized by studies that have consistently increased the number of viable embryos in the uterus on day 30 of gestation, but failed to increase the number of piglets farrowed. Previous studies have demonstrated that it is after day 30 that pig conceptuses begin to actively compete for limited uterine space. Due to the lack of repeatability in the number of pigs born alive after selection for various physiologic traits such as uterine size or ovulation rate, or candidate genes such as the estrogen receptor, little progress has been made. It is for these very reasons that the Chinese Meishan pig was imported to the United States in 1989. The Meishan pig has three to five more pigs per litter than do our United States breeds, while exhibiting an identical ovulation rate and uterine size, making it the ideal model to investigate the mechanism(s) involved in controlling litter size in the pig, independent of these confounding variables.

Over the past 8 years, a basic research approach in our laboratory has elucidated much about the mechanisms responsible for the increased fecundity of the Meishan as compared with commercial pig breeds. Using reciprocal embryo transfer, we have shown that the Meishan conceptus exhibits a decreased placental size on days 30, 70, 90, 110 and at term when compared with Yorkshire conceptuses, regardless of the uterine type in which it was gestated. This decreased placental size would allow more Meishan conceptuses to colonize the uterus after day 30, than is possible for the larger conceptuses of United States pig breeds. Of particular interest is that placentae of United States pig breeds increase their surface area for endometrial attachment proportionally to fetal weight increases throughout gestation, whereas Meishan placentae while not increasing in size, exhibit a marked increase in the density of placental blood vessels designed to increase the rate of nutrient exchange per unit placental-endometrial interface (i.e., increased efficiency).

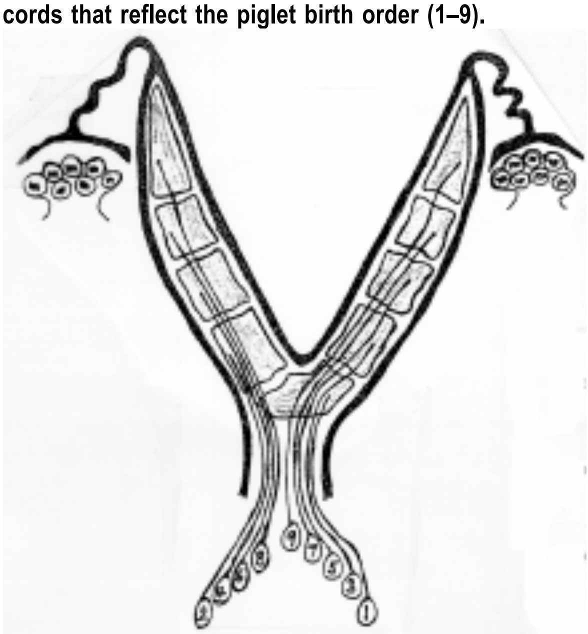
From these data it would appear that thousands of years of selection solely for number of pigs born (with little regard to the conformation, weight or growth characteristics) have resulted in a dissociation of fetal growth from overall placental growth in the Meishan pig. The relative efficiency of the placenta can be estimated by calculating the piglet weight(g):placental weight(g) ratio. In a recent experiment piglet weight:placental weight ratios were calculated for Meishan and Yorkshire conceptuses gestated in either a Meishan or Yorkshire uterus. Meishan conceptuses had ratios of 8.7±0.4 and 6.3±0.5 when gestated in Meishan and Yorkshire females. In contrast, Yorkshire conceptuses had ratios of 4.1±0.9 and 3.4±0.8 when gestated in Meishan and Yorkshire females. The differences in these ratios were due primarily to marked differences in placental size. Further, these data indicate that although there is a maternal effect on placental size, the greatest impact appears to be a result of the conceptus genotype.

Our hypothesis based on these data was that direct selection of breeding stock from our purebred Yorkshire research herd on the basis of piglet weight:placental weight ratios should impact litter size.

Materials and Methods

Eight purebred Yorkshire multiparous sows were bred to Yorkshire boars and monitored immediately prior to and during farrowing at the Iowa State University Animal Reproduction Farm. As each piglet was expelled from the vulva, it was caught and the umbilical cord double ligated with No. 1 braided surgical silk, each with a matched, numbered tag. The umbilical cord was then cut between the tags, allowing the placental end of the cord with its numbered tag to retract into the birth canal (Figure 1). Piglets were ear-notched and weighed at birth and, after expulsion, placentae were collected, and their weights recorded. From these weights we calculated the piglet weight:placental weight ratio for each piglet as an index of placental efficiency. From these piglets, six females and two males with piglet weight:placental weight ratios averaging 5.6±0.3 were selected to establish a high placental efficiency line (A Group) and six females and two males with ratios averaging 3.5±0.2 were selected to establish a low placental efficiency line (B Group). Gilts of both lines were bred by a non-littermate boar within that line (A or B group) at their second post-pubertal estrus. These gilts were subsequently monitored during the period immediately prior to and during farrowing, and piglets and placentae were handled as previously described.

Figure 1. Diagram of the gravid reproductive tract of the pig depicting individual placenta and their tagged umbilical cords that reflect the piglet birth order (1–9).



Results and Discussion

The greatest difference between the parental generation and the selected lines was a 27% decrease in placental weight for the conceptuses from the A Group, with no change in placental weight between parental and B Group litters (Figure 2). There was a slight (18%) decrease in piglet weight between the parental generation and the A Group offspring, again with no change between the parental and B Group offspring. These data would indicate that within a ‘commercial’ line there is significant variation to select for decreased placental size without a detrimental effect on piglet weight.

The piglet weight:placental weight ratio for the eight litters of piglets used to select breeding stock for the first generation averaged 4.2±0.2 with a range of 2.7 to 7.4 (Figure 3). Moreover, differences in this ratio within a litter ranged from 3.8 to 7.4, indicating that a significant amount of littermate variation in placental efficiency existed in our research herd, allowing us to make divergent selection of individuals to produce the A and B groups. For the A Group gilts, the average litter size was 12.3±0.8 and the piglet weight:placental weight ratio averaged 4.8±0.2. Of the B Group gilts, the average litter size for this group was 9.8±0.3 with a piglet weight:placental weight ratio averaging 4.1±0.1.

These data would indicate two very important things. First, that selection for a greater piglet weight:placental weight ratio resulted in an increase in the ratio of nearly 15%, primarily due to a decrease in placental weight. Second, it would appear from this small preliminary data set that selection for increased placental efficiency also positively affected litter size.

Figure 2. Piglet and placental weight for the parental generation (from which breeding animals were selected) and for the offspring of the selected animals (i.e., A and B Groups). Bars represent means ±SEM and different superscripts differ (P<.05).

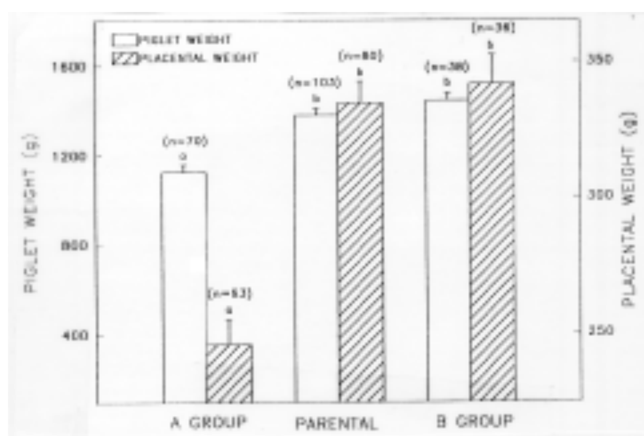


Figure 3. Litter size and piglet weight:placental weight ratio for the parental generation (from which breeding animals were selected and for the offspring of the selected animals (i.e., A and B Groups). Bars represent means ±SEM and different superscripts differ (P<.05).