Research on uterine capacity and litter size in swine

Jeffrey L. Vallet and Bradley A Freking

USDA, ARS, Roman L. Hruska US Meat Animal Research Center, PO Box 166; Clay Center, NE 68933

As the number of available embryos increases, both fetal survival and birth weights of piglets decrease. For many years, it has been possible to increase the number of available embryos through selection for ovulation rate or by hormonal treatment. When this is done, it typically does not result in large increases in litter size, because the uterus of the pig is limited in the number of piglets it can support during pregnancy. This limit has been termed "uterine capacity" and it has been traditionally defined as the ability of the uterus to provide the necessary nutrients to maintain fetuses until farrowing. It has typically been measured as the number of piglets born alive when the number of embryos is not limiting. Although death of the fetus before farrowing is the most serious consequence of limitations in uterine capacity, even when piglets are born alive, these limitations are responsible for runting, which results in reductions in postnatal survival and permanent reductions in growth. The term "uterine capacity" focuses attention on the uterus, but in fact uterine capacity is a combination of the ability of the uterus to provide nutrients, the ability of the placenta to transfer nutrients to the fetus, and the ability of the fetus to efficiently use those nutrients for growth and development. This article summarizes some of the key questions we have tried to answer regarding uterine capacity in swine.

How do we measure uterine capacity? Several methods to increase the number of available embryos in the uterus are available, but many result in highly variable numbers of embryos present within the uterus. Scientists at USMARC (Christenson et al., 1987; click for PDF of publication) used unilateral hysterectomy-ovariectomy (UHO), a surgical method for the removal of one uterine horn and one ovary, to reduce the uterine space available without changing the number of potential embryos. The UHO method is more reproducible, allowing experiments in which treatments to alter uterine capacity can be tested. The method also allowed direct selection for uterine capacity, and led to the development of a line of pigs selected for this trait. Kreg Leymaster and Ron Christenson collaborated on the development of this line. Selection for number of piglets born after UHO treatment for 11 generations resulted in a line of pigs with an increase of 1 extra piglet born per remaining uterine horn, with no change in average piglet birth weight.

When does uterine capacity become limiting during pregnancy? A summary of research on this subject (Vallet, 2000, click for PDF), including some of USMARC research, suggested that fetal death due to limitations of uterine capacity begins to occur shortly after day 30 of pregnancy. More recent results measuring fetal losses in a randomly selected control line, a line selected for increased ovulation rate, and a line selected for uterine capacity, confirmed that most fetal loss due to limitations in uterine capacity in the three selected lines occurs between day 25 and 45 of gestation, but further losses occur during the remainder of gestation (Figure 1). These results also indicate that differences in fetal survival between the uterine capacity selected line and the randomly

selected control line are present by day 45 of pregnancy, and these differences are maintained for the remainder of gestation. Results such as these allow research to focus on periods of pregnancy during which fetuses are particularly sensitive to limitations of uterine crowding. Thus, uterine capacity becomes limiting primarily between day 30 and 40 of pregnancy, but it continues to be limiting until farrowing.

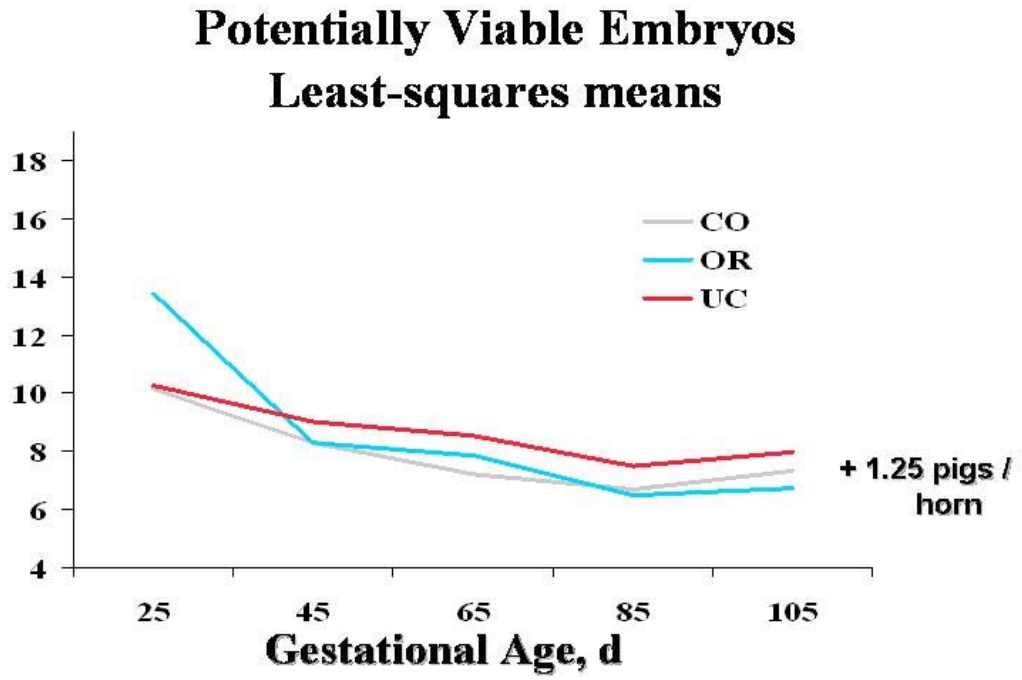

Figure 1: Average number of fetuses in UHO gilts from a randomly selected control line (CO), a line selected for ovulation rate (OR) and a line selected for uterine capacity (UC) throughout gestation is illustrated. Number of embryos decreased most in all three lines from day 25 to 45 of gestation, but the UC line decreased the least. This difference was maintained to day 105 of gestation.

Of the uterine, placental and fetal factors, which ones matter most? We have investigated the effects of intrauterine crowding on uterine protein secretion, and few effects were observed. Others have studied the effects of intrauterine crowding on blood flow, and again few effects were observed. These results suggest few compensatory mechanisms are present in the uterus to respond to intrauterine crowding. However, the size of the uterus is highly variable in pigs, thus there appears to be some opportunity to increase uterine size and function by understanding the basis of this variability. Regarding the fetus, USMARC research has indicated that fetal blood cell development is impaired by intrauterine crowding (Vallet et al., 2002; click for PDF), and other experiments have resulted in the development of a genetic marker associated with uterine capacity and litter size (see below). Most recently, investigation of placental development has indicated differences in the placentas of small fetuses compared to large fetuses within the same litter. These differences are likely to be adaptations or responses to intrauterine crowding experienced by fetuses. Discovery of placental proteins that are associated with these changes, the first step in gaining the ability to improve the

development and function of the placenta, is currently underway. Thus, research suggests that uterine size, fetal red blood cell development and placental function matter. However, research to answer this question is just getting started, and many of the potentially relevant factors have not been examined.

How do pigs selected for uterine capacity differ from other pigs? Studies at USMARC by Larry Young et al., indicated that changes in prepubertal uterine length and weight were genetically correlated with selection for uterine capacity. It has also been demonstrated that fetal hematocrits, which reflect the concentration of red blood cells, are greater in the uterine capacity selected line. More recent experiments also indicate subtle differences in the development of the fetal liver. No differences in the fetal weight to placental weight ratio, which has been suggested to be a measure of placental efficiency, were observed, nor were any differences observed in the development of the placenta. Thus, prepubertal uterine length and fetal red blood cell development are altered in the uterine capacity selected line, but thus far placental development is not. As with the paragraph above, these studies are ongoing.

Are there any other pig breeds with greater uterine capacity, and what can they tell us about how to improve this trait? The Chinese Meishan pig is known to have greater litter size, in part because of increased uterine capacity. USMARC scientists, along with others, imported the Meishan pig into the US in 1989, and were among the first scientists to evaluate its characteristics. Ron Christenson, in collaboration with Steve Ford and others, demonstrated that Meishan embryos develop more slowly than European breed embryos (Anderson et al., 1993; click for PDF). This slower development was associated with reduced uterine protein secretion in the Meishan (Vallet et al., 1998; click for PDF). Other results indicated that the Meishan placenta and fetus were smaller at other stages of gestation (Christenson, 1993). So the Meishan pig tells us that one strategy for increasing uterine capacity may be to reduce the growth rate of the fetus and placenta, with a consequent reduction in the nutrients required for continued development.

Are genetic markers available for uterine capacity? Gary Rohrer, in collaboration with others (Rohrer et al, 1999; click for PDF), identified a region of the swine genome on swine chromosome 8 that was associated with uterine capacity in a Meishan, European breed, crossbred population of pigs. Several genes in this region have been explored as to their potential role in uterine capacity by Jong Kim, a research associate at USMARC, but these experiments have not provided a definitive identification of the gene responsible, and further work is necessary. Recent work by Michelle Moussell confirms that this region is likely to be associated with differences in uterine capacity in other pig populations. In another set of experiments, Drs Jeff Vallet and Brad Freking collaborated to develop a genetic marker for uterine capacity based on the erythropoietin receptor gene (Vallet et al., 2005; click for PDF). This marker was associated with litter size in two different populations of pigs and recent results indicate that it is also associated with changes in expression of the erythropoietin receptor gene.

So, bottom line, how can knowledge regarding uterine capacity be incorporated into strategies to improve pig production? Obviously, swine industry measurement of uterine capacity using UHO is prohibitively difficult. Although it is not a perfect measure, average litter birth weights are likely to be reflective of uterine capacity in large litters. Thus, selection strategies for increased litter size should include emphasis

on average piglet birth weight within large litters. This strategy will help prevent preweaning piglet losses from large litters, because studies have also shown that low birth weight piglets are more susceptible to loss before weaning. The erythropoietin receptor marker and its association with litter size requires further testing in different swine populations for validation, but it represents a potentially useful and currently available genetic marker for increased litter size.