Introduction

Given the potential complexity of swine reproductive problems, the use of a systematic approach to addressing them is important. While a number of strategies can be used, the most effective ones are based on a thorough understanding of the physiology involved with normal reproductive processes. In other words, one needs to know first what should have happened, and then one can use this to help figure out what went wrong.

This article is the first of two that will discuss how knowledge of the physiological processes associated with sow pregnancy, in conjunction with analysis of three production records—farrowing rates, litter size, and the return interval of nonpregnant sows—can be used to identify when and where problems occur. This article reviews the physiology involved with the establishment of pregnancy in sows. The second article will analyze farrowing rate, litter size, and return-interval data to pinpoint when the causes of poor reproductive performance are most likely to occur, based on gestational physiology.

Establishment of Pregnancy

Figure 1 offers a time line showing on one side the major management events during a sow’s production cycle and on the other side the corresponding reproductive processes that must occur in order for pregnancy to be initiated and successfully completed.

In this time line, the day the sow is rebred after weaning is considered to be Day 0 or the onset of pregnancy. Events that occur before and after breeding are designated with negative and positive numbers, respectively, in accordance with how long they occur either before or after the onset of pregnancy. The time line begins with the first day of lactation, which corresponds with the birth of the litter from the previous pregnancy, and ends with the birth of the litter from the current pregnancy. In essence, as soon as one pregnancy ends, physiological processes are initiated that begin to prepare a sow for her next one.

Recovery and Follicular Growth

After farrowing, the reproductive system of sows requires time to recover from pregnancy. The three most important organs involved with this process are the ovaries, the brain, and the uterus. The ovaries contain follicles, which grow in response to two hormones produced by the brain, luteinizing hormone (LH) and follicle-stimulating hormone (FSH). These follicles will eventually ovulate after weaning and release their eggs, which are fertilized during rebreeding. The ovaries recover very quickly, and their follicles are capable of resuming normal growth, if properly stimulated, within a few hours after farrowing.

The brain, as mentioned earlier, produces two hormones, LH and FSH, that stimulate the growth of follicles and eventually cause them to ovulate. The brain’s recovery after farrowing is a two-step process and requires about 12 days. Initially, just after farrowing and throughout most of lactation, low levels of LH and FSH are needed to stimulate the development of small
follies on the ovaries. The brain is capable of this within a few days after farrowing. In contrast, toward the end of lactation and after weaning, increased amounts of FSH and especially LH are needed for the continued development of follicles. The culmination of follicular growth after weaning is ovulation, which requires even higher levels of LH. The brain normally does not acquire the ability to produce sufficient levels of LH and FSH to support the final stages of follicular growth and ovulation until 10 to 12 days after farrowing.

The uterus is where the majority of embryonic and all of fetal development occur during pregnancy. Its recovery also has two phases, but requires between 14 and 16 days under normal conditions. The first event is a decrease in size, which is commonly referred to as involution. During pregnancy, the size of the uterus increases significantly to accommodate the developing piglets. As a result, it must return to its pre-pregnant size before a new pregnancy can begin. This often is complete by 12 days after farrowing.

In addition to involution, the uterus must regain its ability to support developing embryos and fetuses. This requires a repair of the uterine endometrium, the lining of the uterus where implantation, and the secretion of compounds necessary for embryonic development occurs. These processes begin shortly after farrowing, but usually are not completed for 14 to 16 days.

A safety mechanism of sorts is built into lactation to insure that the sow’s reproductive system has sufficient time to recover before it is prompted to resume normal activity. The suckling activity of the piglets during nursing has a quiescent effect on the release of LH and FSH from the brain. There is actually a nerve in each of the teats that, when stimulated, sends a signal to the brain, which allows only low levels of LH and FSH to be released. When piglets are weaned, this inhibition is removed, and the brain releases increased amounts of FSH and LH, which are necessary for the continued growth of follicles and, eventually, ovulation. As a result, lactation not only provides nourishment for the litter from the previous pregnancy, but also provides a period during which the brain and uterus can recover before the next reproductive cycle begins.

It is important to recognize that weaning is the management event that cues the sow’s reproductive system to resume normal activity. If, for some reason, it has not fully recovered when weaning occurs, then a number of reproductive problems may ensue. If weaning occurs very early in the recovery process, then sows usually become anestrous, which is the complete absence of estrous behavior. This condition results when the brain is not able to produce enough LH and FSH to support the final stages of follicular growth. Consequently, sows never have large enough follicles on their ovaries to produce enough estrogen, the hormone responsible for causing estrous behavior.

An abnormally long and erratic estrous period is referred to as nymphomania and also is related to the incomplete recovery of the brain. This situation occurs when the brain can produce enough LH and FSH to support the final stages of follicular growth, but lacks sufficient amounts for ovulation. Follicles grow and produce estrogen in sufficient quantities to stimulate the standing reflex, but never actually ovulate. Sows with this condition do not conceive when they are bred because there are no eggs to fertilize since ovulation does not take place.

These two conditions, anestrus and nymphomania, are fairly easy to detect because they represent deviations from normal estrous behavior after weaning in sows. A more difficult situation to identify is when the recovery of the brain is complete, but that of the uterus is not, when weaning occurs. The frequency at which this occurs probably is higher than most people realize since the brain usually recovers 2 to 3 days earlier than the uterus. Estrus is normal in these sows and, if bred with viable semen, their fertilization rate is high. In essence, everything from a behavioral perspective appears fine. However, pregnancy is not maintained because the uterus has not recovered sufficiently to support embryonic development. The results are low farrowing rates and a reduction in litter size.

In general, if sows are managed well and lactate for at least 14 to 16 days, then the general assumptions are that the ovaries, brain, and uterus are fully recovered and the reproductive events triggered by weaning should progress without any problems. However, it is important to recognize that sows may experience a number of situations in production that may short-circuit the recovery process. Recovery may be delayed, so it takes longer, or, even though there are piglets nursing, the reproductive system may be prompted to resume activity before recovery is complete.

From a physiological perspective, it is reasonable to assume that sows that lose significant body weight and body condition during lactation probably have extended recovery periods. In general, as body weight and condition improves, nutrient availability to reproductive organs decreases. In other words, if the amount of nutrients going to support lactation increases, fewer will be left for the recovery of the ovaries, brain, and uterus. Since feed intake during lactation is closely linked to loss of body weight and condition, sows with reduced appetites may, on the average, require longer periods of recovery than their counterparts that maintain high intake levels. For most herds in the southeastern U.S., and especially North Carolina, this is particularly relevant. Feed consumption during lactation normally decreases during the hot summer months. As a result, within a herd, the recovery of the sows’ reproductive systems most likely will take slightly longer in the summer, compared with other seasons.

As mentioned earlier, inhibition of LH and FSH secretions by the nursing activity of the litter during lactation is physiologically how the sow’s body keeps the reproductive organs in a quiescent state so they have ample time for recovery. Therefore, any reduction in the number of pigs or in the intensity of nursing effectively reduces this inhibitory effect. As a result, even though there are still pigs nursing, the suckling-induced inhibition is not great enough to keep secretion of LH and FSH in check, and the sow’s reproductive system attempts to resume normal activity. Thus, the nursing activity reaches a point that is so low that the sow physiologically behaves as though her litter has been weaned.

Two production situations in which this can occur are on farms using partial weaning strategies and in litters with small pigs that aren’t nursing vigorously. In the case of partial weaning, the physical removal of the largest pigs several days early might reduce the suckling intensity enough to stimulate the recovery process prematurely. Likewise, in the case of litters of small pigs, the reduction in suckling intensity comes from the lack of nursing activity. In both cases, the result, physiologically, is the same—resumption of reproductive activity before recovery is complete.
Fertilization and First and Second Pregnancy Signals

From a physiological perspective, fertilization requires that sufficient numbers of fertile spermatozoa be present in the oviduct several hours before ovulation. From a management perspective, things such as semen quality, detection of estrus, and the technical competence of breeding technicians all play important roles in the relative success or failure of fertilization. However, provided that these are all done reasonably well, fertilization rates in pigs are usually very high, often exceeding 90 percent. This is an important point to remember when identifying causes of suboptimal reproductive performance. Problems with fertilization are almost exclusively external rather than internal. In other words, they typically aren’t related to failure of some aspect of sow physiology, but rather the result of a management deficiency, such as poor detection of estrus, etc.

After fertilization, embryos remain in the oviduct for several days and then enter the uterus. During this period they are in what is termed a “free-floating” stage in which they exist “unattached” in the uterine lumen. Around day 12 of pregnancy they begin to elongate and produce estrogens. This local production of estrogens by the embryos is the first signal to the sows to let them know that they are pregnant. The estrogens prevent the release of a hormone called prostaglandin \( F_2 \alpha \), which normally causes regression of corpora lutea and, thus, terminates the production of progesterone, a hormone necessary for the maintenance of pregnancy. At least 5 viable embryos need to remain in the uterus by day 12 in order for enough estrogen to be produced to prevent the release of prostaglandin \( F_2 \alpha \). If there are less than 5, then sows never know they are pregnant, prostaglandin \( F_2 \alpha \) is released, and progesterone decreases. The result is that sows return to estrus 18 to 21 days after their initial breeding.

If sows receive the first signal by day 12, then pregnancy is maintained. The embryos continue their elongation process and actually begin to form attachments with the uterine endometrium. This is commonly referred to as the beginning of the implantation process. Sometime after day 17 and before day 28 of pregnancy, the developing embryos initiate a second period of estrogen production. It is thought that this second pregnancy signal is associated with the development of the fetal portion of the placenta. There also must be at least 5 embryos present to cause enough production of estrogen for pregnancy to continue. If there are less than 5 during this period, then sows usually return to estrus 28 to 35 days after they were bred.

The length of time it takes nonpregnant sows to returns to estrus after breeding is directly related to the occurrence of the two pregnancy signals. If sows do not have at least 5 viable embryos by day 12, then they will return to estrus 18 to 21 days after they are bred. This is commonly referred to as “regular returns” to estrus. This situation could arise either from fertilization failure or from high embryonic losses during the first two weeks of pregnancy. In contrast, if sows receive the first pregnancy signal on day 12, but do not receive the second signal, then they will return to estrus, on average, 28 to 35 days after breeding. This is commonly referred to as “irregular returns” to estrus. This situation occurs normally when there is an increased loss of embryos between days 12 and 28 of pregnancy. The normal physiology associated with the establishment and maintenance of pregnancy during its first month is the primary reason why it is so important for swine operations to accurately monitor the return-to-estrus interval of nonpregnant sows. Problems that arise during the first two weeks result in “regular returns” to estrus, and those that arise during weeks 3 and 4 cause “irregular returns” to estrus.

Fetal Development

After day 30, implantation is complete and the developing embryos begin to resemble live pigs, so they are referred to as fetuses. In addition, no minimum number of fetuses needs to be present in order for pregnancy to continue. It seems that once sows receive the second pregnancy signal between days 17 and 28, corpora lutea and progesterone production are usually maintained until term. This is one reason why litters of one or two pigs and pseudopregnancy (commonly referred to as “sows that are not-in-pig”) occur. Physiologically, what happens in each of these situations is that there were at least 5 viable embryos present on day 28, because sows never returned to estrus. However, in both conditions, fetal death after day 28 occurred to such an extent that, in the case of litters with one or two live pigs, there were only a few viable ones left or, in the case of pseudopregnancy, none survived to term.

In situations where high fetal death losses occur, an estimation of when during gestation they occur is possible if the average number of mummified fetuses and stillborn pigs
per litter is recorded. During fetal development, the skeleton initially is composed mostly of soft tissue. Between days 50 and 60 of gestation, calcification of this soft tissue begins. When fetuses die before days 50 to 60, sows can break down and reabsorb most of the fetal remnants. In contrast, if fetuses die after days 50 to 60, then sows can reabsorb only the soft tissue, not the bones that are in the process of being calcified. Consequently, fetal deaths after day 50 to 60 usually end up as mummified fetuses. The size of the mummies and their degree of deterioration are related to how long they have been dead. Small mummies with significant deterioration died shortly after calcification began, whereas those that are large and mostly intact probably died 2 to 3 weeks before farrowing.

Stillborn pigs are normal pigs morphologically that are born dead. Most stillborn pigs die during the last week of pregnancy or during farrowing.

Based on the normal course of fetal development, the following observations can be made. Pseudopregnancy and small litters with no stillborns or mummies result from problems between days 30 to 50 of gestation. Small litters with a high number of mummies arise when problems occur between days 60 to 100. Finally, small litters with a high number of stillborns are caused by problems that occur during the last week of gestation or during farrowing itself.

The obvious exception to the normal physiological events that occur during fetal development is an abortion. Abortions result from situations in which the mechanisms that initiate farrowing occur prematurely. This results in the expulsion of all or part of the developing fetuses. Production of cortisol by fetuses is believed to initiate the cascade of events that result in farrowing. Probably, the most important thing that the production of cortisol by fetuses does is to stimulate the release of prostaglandin F$_2$α. Prostaglandin F$_2$α causes progesterone to decrease, which is necessary for farrowing to begin. Therefore, any event that stimulates large increases in either cortisol or prostaglandin F$_2$α can cause pregnant sows to abort.

This is important because cortisol and prostaglandin F$_2$α are two hormones that are also produced by sows exposed to stress. For example, sows that are heat-stressed or receive social and physical insults can release high levels of these hormones. There is some question as to whether cortisol produced by sows, as opposed to that produced by fetuses, can ever reach high enough concentrations in the uterus to cause abortions. However, from a management perspective, it is probably wise to assume that this can happen.

Summary

Key physiological events in the establishment and maintenance of pregnancy begin with recovery of the reproductive system during lactation and end with the successful completion of fetal development, which is terminated by farrowing. Next month’s issue will discuss strategies for using this information in conjunction with data on farrowing rate, litter size, and return interval of nonpregnant sows to pinpoint when problems occur.

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