

Physiological mechanisms mediating embryonic survival in pigs

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The number of pigs weaned per sow per year is an important measure of reproductive efficiency in the swine industry. Litter size directly affects this measure and therefore great efforts are made to improve litter size and consequently increase the number of pigs weaned.

Studies have shown that pre-natal mortality can have a great impact on litter size. It is generally accepted that 20 to 30% of the embryos die during the first 30 days of gestation, with an additional 10 to 20% dying from days 40 to 100. The conceptl die during these two periods by different mechanisms, and this presentation will focus on the mechanisms mediating the survival of conceptl during the first 30 days of gestation.

Nutrition can affect embryo survival, and it may exert its effects at different reproductive stages. It has been demonstrated in gilts that a reduction in feed intake during days 8 to 15 of the estrous cycle will decrease embryonic survival rate by about 15%. Probably, any nutrient deficiency at this particular period can affect follicular development and the maturation of the oocytes, thus the further development of embryos will be compromised. Other studies have shown that changes in energy intake, or insulin injections, during the last 10 days of the cycle may be beneficial in maximizing ovulation rate. However, the effects on litter size are unknown. The level of feeding during early pregnancy has also been shown to influence embryo survival. This factor may act indirectly through effects on the levels of circulating progesterone, an essential hormone for the maintenance of pregnancy.

Implication

Understanding the mechanisms mediating pre-natal mortality can ensure that embryonic survival does not limit litter size. This will contribute to an increase in reproductive efficiency, which is an important goal in the swine industry.

Role of the oviduct in embryonic loss during early pregnancy in the pig.

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As pork production in Alberta becomes increasingly more intensive, efficiency in sow herd in terms of litter size is being stressed. More demands are being placed on the replacement gilt and sow in terms of litter size and fertility to increase the number of pigs weaned per sow per year. There is a need to understand the mechanisms of embryonic loss and in turn, formulate appropriate management strategies to maximize litter size.

Our research group is currently investigating how nutrition during various stages of the reproductive cycle can adversely affect embryonic survival in gilts and sows. The nutritional studies demonstrate that a lower embryonic survival is associated with lower progesterone concentrations during early pregnancy, and that giving exogenous progesterone therapy can in part restore embryonic loss in those pigs.

This suggests a common underlying mechanism may be responsible for the embryonic loss seen in these studies.

Circulating steroids in early pregnancy are responsible for producing an appropriate environment for the specific events occurring in the oviduct, such as gamete maturation and transport, fertilization and early embryonic development and in preparing the uterus for the implanting embryo. The porcine oviduct secretes proteins (POSP 1-3) that have been shown to bind to oocyte membranes and incorporate into the early cleaving embryo. In other species similar oviduct proteins have been shown in vitro to enhance fertilization rates and improve implantation. These proteins are secreted during the peri-estrus period and the secretion of these proteins is thought to be steroid induced, which suggests that differences in steroids during early pregnancy may affect the quality of the oviduct environment. We do not know yet the specific functions of these proteins, nor fully understand the relationship between steroids and their synthesis and secretion. Thus far, studies have concentrated on peripheral steroid concentrations in relation to oviduct environment, yet from our previous work peripheral steroid concentrations may not necessarily reflect the steroid concentrations present in the sub-ovarian counter-current system. Insight into the local steroid concentrations may help explain this relationship further. The objective of this presentation is to demonstrate how the oviduct may play a role in embryonic loss.

Implication: Insight into the control of oviduct protein secretion by steroids and the

role of the oviduct in embryonic loss will facilitate appropriate sow and gilt management to maximize litter size and ultimately production efficiency.

Optimizing timing of AI in gilts

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Determining the optimal time of artificial insemination in gilt breeding programs is very important to ensure successful fertilization and to improve reproductive efficiency. A number of different factors influence the success of fertilization. These factors include the life-span of a sufficient number of fertile spermatozoa to ensure fertilization, the speed of sperm transport and sperm capacitation, and the life-span of the oocytes. Other than semen quality, successful fertilization depends mainly on the time of insemination relative to ovulation.

If insemination is performed too late, deleterious effects on fertility can be seen as reduced conception rates, a lower incidence of normal fertilization and increased embryonic loss. The life-span of the oocytes in the fallopian tubes is around 8 to 10 hours. Aging of the oocytes before sperm penetration occurs is the likely cause of the detrimental effects. Conversely, if insemination is carried out too early, fertility is negatively effected due to aging of the sperm. 24 hours or less has been estimated to be the optimal range for insemination to ovulation interval based on sperm survival in the reproductive tract of the female pig. In order to determine the optimal time for insemination, it is necessary to accurately predict the time of ovulation. Transcutaneous ultrasonography of the ovaries is a non-invasive, stress free method by which follicular growth and the exact moment of ovulation may be monitored.

A study was carried out at the Swine Research Unit of the University of Alberta to determine when ovulation occurs in relation to estrus duration in gilts and to predict what would be the optimal time of insemination in these animals. 54 cyclic Camborough x Canabrid gilts were used. Estrus detection was carried out every 6 hours starting on day 19 of the cycle. The onset of estrus was determined using the "back-pressure test" and 24 hours after estrus onset, ultrasonography was carried out every 6 hours to establish the exact time of ovulation. Results show that, as in the sow, time of ovulation is highly related to estrus duration, but in these gilts ovulation occurred at about 87% of estrus duration. Previous studies using sows have reported that ovulation took place after approximately 70% of the estrous period. These findings suggest that different breeding strategies should be adopted for sows and gilts.

Implication:

Accurate prediction of moment of ovulation in gilts is important to determine the

optimal time for artificial insemination. This will contribute to an improvement in fertilization rate and reproductive efficiency of the breeding herd.

Use of Regumate in gilt breeding programs

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In gilt breeding programs synchronization of the estrous cycle has many advantages for the farmer. For example, the use of an all-in all-out system, which includes improved herd health, better organization and distribution of work, and an optimized use of buildings.

Regumate can be used for the synchronization of breeding in gilts. This product is a synthetic steroid (17α -allyl- 17β -hydroxyestra-4,9,11-trien-3-one) with a similar structure and function to progesterone. The estrous cycle of the gilt and the sow lasts on average 21 days and is divided into two phases. The follicular phase in which estrogen is secreted and follicles grow for 5 to 6 days, ending in estrus and ovulation. In the luteal phase the corpora lutea develop and secrete progesterone. The function of progesterone is to block the pattern of secretion of follicle stimulating hormone (FSH) and luteinizing hormone (LH), necessary for the growth of new estrogen secreting follicles. In the absence of pregnancy the corpora lutea regress after 14 to 16 days and a new cycle starts with the follicular phase. The role of Regumate as a progesterone analog is to continue the "luteal" phase. As long as Regumate is used the gilt does not enter the follicular phase and will not ovulate or show estrus.

To show the efficiency of Regumate treatment, cyclic gilts were allocated to specific breeding weeks, targeted to provide batch farrowing of gilts during the regular working week (Monday to Friday). The heat of 334 gilts was synchronized by feeding Regumate for between 5 and 18 days at a dose of approximately 18 mg (8 ml) of product per day. Regumate was withdrawn on the Wednesday before the start of the target breeding week. All gilts were bred twice by AI, 12h and 24h after onset of standing heat.

Within 7 days after withdrawal of Regumate 100% of the gilts were in heat. The average duration of Regumate treatment across all gilts was 12 days. The conception rate was 88% (based on 150 gilts) and the average litter size 10.13 (range 1-15) piglets (based on 76 litters). To use Regumate in this way, the time of the previous heat must be known and then Regumate is used from day 15 of the luteal phase until the Wednesday of the week before breeding is scheduled.

Implication: Regumate can be used to synchronize estrus in gilts. After withdrawal

of Regumate gilts are bred at prescribed times with high fertility.

Factors affecting reproductive performance in the first-litter lactating sow

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Voluntary feed intake in first-litter lactating sows usually is insufficient to meet the requirements for lactation. Thus, these sows lose excessive weight and condition during lactation resulting in decreased reproductive performance after weaning. In a series of experiments we have examined the effect of feed restriction during lactation on reproductive performance in first-litter lactating sows suckling different sized litters.

The purpose of this review of available data from these experiments is to consider the relative importance of feed intake and litter size for fertility after weaning. Comparable production and fertility data are shown in Table; AA-6 sows suckled 6 piglets and were fed to appetite through a 28-d lactation; AR-6 sows suckled 6 piglets, were fed to appetite from d 1 to 21 of lactation, then feed restricted to 50% of to-appetite intake between d 22-28; AA-9 sows were fed as AA-6 sows, but suckled 9 piglets. The larger litter size in AA-9, and feed restriction in AR-6, caused more body weight loss compared to AA-6 sows. Milk production (litter weight gain) of AA-9 sows was higher than those of the other groups. Weight loss from both feed restriction and higher litter size decreased sow fertility, with weight loss in late lactation having the greatest effect on sow fertility after weaning.

Treatment	AA-6	AR-6	AA-9
Litter size	6	6	9
Feed intake, kg/d, Week 1-3	4.1	4.1	4.6
Week 4	5.2 ^a	2.1 ^b	5.8 ^a
Litter gain, g/d	1530 ^a	1554 ^a	2358 ^b
Body weight change, kg, d 1-28	-11.0 ^a	-21.0 ^b	-19.4 ^b
Weaning-to-estrus interval, h	88.7	122.3	106.5
Ovulation rate	19.9 ^a	15.4 ^b	17.9 ^{ab}
Embryonic survival rate, %	87.5 ^a	64.4 ^b	69.0 ^{ab}

Implication

To maximize first-litter sow productivity, lactation weight loss should be controlled by fostering piglets from the first-litter sows to higher parity sows and by maximizing feed intake during lactation. Feeding strategies to achieve this goal are presently

being investigated.

Method of boar exposure on puberty attainment in gilts

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The time in which a gilt will reach sexual maturity is dependent on a number of factors: age of gilt, genotype, environment (temperature and photo-period) and the social interactions she is exposed to. Holding all other components constant, we tested the effect of different social interactions on the ability to attain puberty. Two components of the social interactions tested were boar stimuli and housing (in regards to the method of boar exposure). Boar stimuli can be divided into visual, tactile, auditory and olfactory cues. The method of housing (stall vs. pen) will thus determine the amount and type of boar exposure the gilt receives.

In two replicates, 21 gilts were assigned to stalls and 50 to pens. Twice a day for a minimum of ten minutes, gilts were exposed to a mature vasectomized boar. For stall housed gilts, the boar was run in front of the stalls. Pen housed gilts were further divided into two groups, 25 gilts were taken to the boar pen (boar-gilt) and for the remaining gilts (n=25) the boar was taken to the gilts' pen (gilt-boar) for puberty stimulation. Puberty was assessed as the standing reflex to back pressure testing while in fenceline contact with a boar. The following data was collected at puberty.

Treatment	Age (days)	Weight (kg)	Backfat (mm)	Duration of Estrus (h)	Percent Pubertal
Stalls	186.2 ^a	139.2 ^a	17.3	43.1	85
Gilt - Boar	179.7 ^{ab}	124.3 ^b	15.8	33.5	96
Boar - Gilt	176.2 ^b	129.0 ^{ab}	15.1	39.2	81

^{a,b} means within column with different superscripts differ $P \leq 0.05$

Implication

These results indicate that the most effective way to stimulate puberty in gilts is through direct contact with a boar. Since a larger proportion of gilts did not reach puberty by 215 days in boar to gilt compared with gilt to boar, it is recommended that the most efficient way to stimulate puberty is by taking gilts to the boar pen.

Limiting protein loss in lactation maximizes first-litter sow performance

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Modern sows are larger, leaner, produce more milk but have smaller appetites than sows prior to the 1990's. As a consequence sows often lose large amounts of live weight during lactation. This is associated with reductions in milk production and subsequent reproductive performance, and is especially prevalent in first-litter sows. Weight loss is composed of both protein (lean) and fat tissue. We believe that loss of too much protein during lactation contributes to the decline in production observed, and we define the level of protein loss more than which production declines as the 'threshold level of protein loss'. In order to test whether sow performance declines once sows lose more than the threshold level of protein we fed first-litter sows an isocaloric diet (62 MJ DE/d) during lactation to lose either:

1. **Less than the 'threshold'** (868 g CP/d and 49.6 g lys/d) level of protein;
2. **The 'threshold'** (650 g CP/d and 34.8 g lys/d) level of protein; or
3. **More than the 'threshold'** (519 g CP/d and 25.6 g lys/d) level of protein.

Sows fed to lose more than the threshold level of protein during the 24 d lactation lost more weight (-28.2 kg) than sows fed to lose either less than the threshold level of protein (-12.7 kg), or the threshold level of protein (-17.0 kg). The fact that there was no difference in backfat loss among treatments (-1.3 mm) strongly suggests that the difference in weight loss seen among treatments was mainly protein tissue.

In support of our hypothesis, subsequent fertility was reduced in sows that were fed to lose more than the 'threshold' level of protein during lactation, as indicated by 70% fewer medium (4 to 6 mm) follicles on the ovary at weaning. Furthermore, although piglet and litter growth rate did not differ among treatments, milk protein concentration declined ($P = 0.06$) in late lactation in sows fed to lose more than the threshold level of protein. In addition, litter growth rate declined in sows that lost more than 25 kg of live weight in lactation, or 12 to 15% of their lean body mass.

Implication

Limiting maternal protein loss during lactation ensures first-litter sows maintain milk production throughout lactation, and rebreed promptly and successfully after weaning.

Leptin: An indicator of body condition and reproductive performance?

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Several studies have demonstrated a relationship between nutrition, body condition and reproductive performance. Leptin, a recently discovered hormone produced in fatty tissue and associated with metabolic status, may be a link between nutrition and reproduction. Leptin deficient mice are infertile and exogenously administered hormone restores fertility. Leptin also regulates satiety. Feed intake during gestation and backfat thickness at parturition are thought to be the most important factors regulating lactation feed intake. Aherne et al. (1998) have suggested that a backfat depth of greater than 25 mm at parturition is required before lactation feed intake is affected.

It is well established that poor feed intake during lactation will adversely affect subsequent sow fertility. Low or absent leptin concentrations have been associated with low gonadotrophin levels and poor follicular development. Therefore, the objective of the present study was to determine whether plasma leptin concentrations during lactation or after weaning were related to lactation feed intake and subsequent reproductive performance.

At farrowing, 205 sows were blood sampled and backfat measurements taken. A further 210 sows were blood sampled and backfat measurements taken at weaning. Daily feed intakes were recorded for the duration of lactation for both groups of sows. Blood samples were analyzed for leptin concentration at the time of parturition and weaning. Regression analyzes were performed to determine relationships between circulating leptin concentrations, lactation feed intakes, backfat thickness, weaning to estrus intervals and subsequent litter

Implications

Measuring circulating leptin concentrations may provide a simple and accurate method to determine the metabolic status of an animal. By regulating the circulating levels of leptin we may be able to regulate reproductive function.

The effect of prostaglandin injection at insemination on sow fertility and fecundity

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The use of artificial insemination (AI) to breed sows and gilts is growing dramatically. However, some sows perform poorly when bred using AI, for reasons as yet undetermined. Several studies implicate the absence of naturally occurring seminal plasma hormones and proteins, which are removed during semen processing and extension. It is also of importance that appropriate numbers of viable sperm cells be present at the site of fertilization to ensure fertilization of oocytes. Therefore, timing of AI is crucial in order to obtain desirable fertilization rates. Natural matings often achieve higher conception rates and increased litter size, possibly due to advanced ovulation and improved synchronization between sperm and ova resulting in higher fertilization rates. Improved sperm transport, facilitated by uterine and oviductal contractions mediated by oxytocin release, may be one mechanism where natural vs AI matings differ. Estrogen in seminal plasma causes the release of endogenous prostaglandin (PGF) which results in the release of oxytocin. Weiler and Claus (1991) showed that trans-cervical infusion of PGF advanced ovulation by approximately 12 hours. Furthermore, Pena et al. (1998) have shown that an injection of PGF at the time of AI improves conception rate and litter size during the summer months when infertility has tended to be problematic.

Studies were conducted at two commercial units during the Summer months. At the first site, sows were given either an intravulval injection of oxytocin or PGF at time of insemination or no injection (control). At the second site, sows were given either intravulval injection of PGF at time of first insemination (1 injection) or injection of PGF at each insemination (2 injections of PGF) or no injection (control). Conception/farrowing rates and subsequent litter size was recorded.

Implications

The primary objective of these studies was to provide a method to optimize the timing of artificial insemination and thereby improve farrowing rate and litter size.

hCG induces a prolonged luteal phase in gilts

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Objective

To determine the efficacy of a single injection of human chorionic gonadotrophin (hCG) for the induction of a prolonged luteal phase in gilts.

Materials and methods

Forty-four PIC Camborough prepubertal gilts (86 kg BW) were assigned to receive an injection (IM) of 1000 IU hCG (Chorulon[®], Intervet Canada) on day 12 of their estrous cycle (n=24) or no injection and serve as controls (n=20). Boar exposure for estrus detection was implemented from day 15 until the end of the study and blood samples were obtained at 20 and 30 days for progesterone determination. Control gilts were allowed to cycle with no further intervention. Gilts receiving hCG and not showing estrus by day 30 received 175 mg cloprostenol (IM) to initiate luteolysis. Gilts returning between 17 and 24 days were considered to have had a cycle of normal duration.

Results and discussion

Of the 20 control gilts, 16 had normal cycles, 1 had a short cycle (16-d) and 3 had long cycles (mean 30-d). Of the 24 hCG treated gilts, 1 had a normal cycle, 1 had a short cycle (14-d), 15 had long cycles (mean 33-d) and 7 were not detected in estrus and were considered to be either estrus detection failure or failure of luteolysis. Of the 15 gilts exhibiting long cycles, 2 were detected as estrous on day 30 (day of PGF injection), 5 were estrous on day 31 and 1 was estrous on day 32.

Since the objective of the PGF was to induce luteolysis and initiate the follicular phase, these extremely rapid responses suggest that natural luteolysis had already occurred. Therefore, while these data support the hypothesis that hCG administered at day 12 of the estrous cycle will effectively prolong the luteal phase, an extension beyond 7 to 10 days is not always realized.

Implication

More work is needed but these data suggest that hCG can be used to control estrus.

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Human chorionic gonadotropin at parturition fails to consistently induce ovulation in sows

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Objective

Two experiments were performed to examine the efficacy of hCG for induction of ovulation in sows immediately after farrowing and (experiment 2) the effect of hCG treatment on sow reproductive performance after weaning.

Method

For experiment one, 69 mixed parity sows on two commercial units in Alberta received 1000 IU hCG at varying intervals within 24-hours of farrowing. Blood samples were obtained 7 to 10-days later for determination of progesterone (P₄) as an indicator of ovulation. For experiment two, mixed parity sows from a commercial unit in Kansas were assigned by parity to receive a vulval-mucosal injection of 1000 IU hCG (n=240), or no injection (control; n=152), within 24 hours after farrowing. Of the hCG-treated sows, 122 also received a vulval-mucosal injection of 250 mg cloprostenol (PGF) 14-days after farrowing. Pigs were weaned at 10-days of age and sows bred at their first observed estrus after weaning.

Results

For experiment one, hCG injection caused ovulation in at most 57% of sows, as indicated by plasma P₄ concentrations of more than 5 ng/ml. For experiment two, hCG- and hCG+PGF-treated sows had longer (P<0.001) farrow-to-estrus intervals, and these intervals had a biphasic distribution. However, subsequent litter sizes were not different.

Implication

These results demonstrate that the ability to induce ovulation in farrowed sows with hCG is too unpredictable to be of commercial value.