INFLUENCE OF HOUR OF WEANING ON ENDOCRINE CHANGES AND REBREEDING PERFORMANCE OF SOWS

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Kelly Bowen

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ABSTRACT

Two trials were conducted to determine the effect of hour of weaning on endocrine changes, weaning-to-estrus interval (WEI), and rebreeding performance of sows. A total of 84 Cotswold sows of mixed parity were used in a completely randomized design. Sows were maintained in a cycle of 9h light:15h dark from day 105 of gestation. After an 18-day lactation sows were weaned at either 0800h (AM; immediately after lights-on) or 1645h (PM; immediately before lights-off). Eighteen sows were fitted with indwelling ear-vein catheters on the day before weaning. Sera, from blood samples taken at 30-minute intervals from the day of weaning to the second day of standing estrus, were analyzed for luteinizing hormone (LH), estradiol, and progesterone. All sows were monitored for WEI, synchronization of post-weaning estrus, pregnancy, and subsequent farrowing performance. Sows were naturally inseminated on the first day of estrus followed by AI at approximately 10 and 24h.

There were no significant differences in WEI between sows weaned at 0800h (99.59h ± 5.52) and sows weaned at 1645h (106.63h ± 5.52). However, the AM-weaned sows returned to estrus with greater synchrony than the PM-weaned sows ($P<.01$). Pregnancy rate, farrowing rate, litter size, number born alive, still born, and mummies from the subsequent breeding and farrowing were not affected by treatment. No

significant differences were found between treatments for mean estradiol, progesterone, or LH concentrations on day of weaning, day after weaning, day before estrus, nor the first and second days of estrus. Likewise, no differences were detected between estradiol surge duration, estradiol maximum peak value, hours from weaning to beginning of estradiol surge, hours from weaning to peak of estradiol surge, LH baseline concentration, LH surge duration, LH surge peak value, LH pulses per sampling period, hours from weaning to beginning of LH surge, hours from weaning to LH peak value, or the interval from the estradiol peak to the LH peak. A positive correlation was seen between the time from weaning to LH surge peak and WEI regardless of treatment. AM-weaned sows had a greater proportion of estradiol surges beginning during the scotoperiod ($P<0.025$) and tended to have a greater proportion of peak LH surges during the early scotoperiod ($P<0.1$) than did sows weaned at 1645h. Accurate prediction of the LH surge and thus ovulation would result in increased inseminations at optimal times. This study better illustrates the importance of a defined weaning time on WEI synchrony and the timing of optimal insemination in sows.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

LIST OF ABBREVIATIONS

ADFI	average daily feed intake
AM	sows weaned at 0800h
BSA	bovine serum albumin
CL	corpora lutea
cpm	counts per minute
CV	coefficient of variation
E_2	estradiol 17-β
FSH	follicle stimulating hormone
GnRH	gonadotropin releasing hormone
i.m.	intra muscular
IU	international units
kg	kilogram
LH	luteinizing hormone
LHRH	lutenizing hormone releasing hormone
ME	metabolizable energy
mg	milligram
ng	nanogram
NRC	National Research Council
NRS	normal rabbit serum
P4	progesterone
PBS	phosphate buffered saline
PEG	polyethylene glycol
pg	picogram
PM	sows weaned at 1645h
RIA	radioimmunoassay

rpm	revolutions per minute
SAS	Statistical Analysis System
WEI	weaning to estrus interval

CHAPTER 1

INTRODUCTION

Manipulation of the sow's reproductive cycle to increase productivity is a main area of focus for researchers and producers alike. The gestation length of 114 days (102d - 128d) (Hafez 1993) is a fixed interval that cannot be manipulated without damaging effects to the litter. Therefore, other segments of the reproductive cycle have been examined. One key area is that of lactation length, resulting in the practice of early weaning at approximately 10 – 18 days of age. The purpose of early weaning is to remove the suckling-induced inhibition of estrus, thereby hastening the sows return to estrus and subsequently, a state of pregnancy. While early weaning decreases the number of days used for lactation, potentially increasing the productivity of the sow, it can also have negative effects on reproductive performance. These can include an increase in the weaning-to-estrus interval (WEI) and/or smaller subsequent litter size (Foxcroft et al 1995).

The time during which the sow is not in an active state of productivity, i.e. pregnant or lactating, is referred to as non-productive days (NPD). Decreasing the NPD is a goal of many producers. Fewer NPD increases profitability with respect to the number of piglets produced per sow per year, and maximizes efficient use of barn space,

in both farrowing and breeding areas. Long and irregular WEI in a breeding herd results in higher numbers of NPD and therefore higher cull rates; an expensive and potentially wasteful procedure.

Much research has been done in an attempt to determine the exact physiological factors that cause problematic WEIs, or, for that matter, prevent them. Some of these factors include: nutrition and the metabolic state of the sow both during and after lactation; housing types; social interactions; and seasonal effects. Sows are responsive to light patterns and their ancestral wild counterparts are short-day breeders (Kermabon et al 1995, Delcroix et al 1990). A short-day photoperiod appears to be optimal for reproductive performance of the domestic sow as well (Kermabon et al 1995, Foxcroft et al 1995). Seasonal effects in a domestic breeding herd during the long days of summer can manifest themselves as increased WEI, decreased ovulation rates and litter size, and an increase in abortion rate (Claus and Weiler 1985, Smith et al 1991, Peltoneimi et al 1999). Some of these seasonal effects are thought to be mediated by endocrinological factors, such as luteinizing hormone (LH) activity, estradiol activity, and progesterone concentrations (Peltoneimi et al 1997a, Love et al 1993, Smith et al 1991).

Recent evidence has suggested a strong relationship between time of weaning relative to the onset of light (i.e. lights-on or lights-off) (Evans et al 1996). Influence of the time of weaning appears to affect hormone profiles including that of LH. Evans et al (1996) suggested that ovulation, and therefore a fixed insemination time without estrus detection, can be determined for sows kept under 14 hours light:10 hours dark and weaned at 0400h (2 hours before light-on). In spite of these data, the potential relationship between photoperiod/time of weaning and estrus onset remains unclear.

The main objective of this research was to determine the effect of hour of weaning relative to lights-on and lights-off on LH, estradiol, and progesterone activity, WEI, and rebreeding performance in sows kept under a short day light regime. Based on the research by Evans et al. 1996, it is hypothesized that those sow weaned at 0800h, immediately after lights on will display a more synchronous estrus and an endocrine profile that would allow an accurate determination of ovulation, thereby allowing an optimal insemination time.

By determining differences between sows weaned immediately after lights-on and those weaned immediately before lights-out, a better understanding of the mechanisms that control and influence post-weaning reproductive performance will be attained. This will assist producers in developing suitable management strategies in both the farrowing and breeding barns to help maximize the sow's reproductive productivity and efficiency.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

Today's hog production systems are demanding higher and higher reproductive performance and efficiency from the domestic sow. The efficiency of the breeding sow can be measured in litters (or pigs) per sow per year, lactation length, and non productive days (NPD). The goal of the producer is to maximize the number of piglets per sow per year, and minimize her NPD. The NPD are those days in which the sow is not actively nursing a litter or in a state of pregnancy.

By decreasing the sow's lactation length, her potential for a greater number of pigs per year is increased. It has become increasingly popular in the swine industry to use early weaning of piglets, at approximately 10 to 21 days, as a standard production practice. This practice is seen as enabling producers to maximize the number of pigs per sow per year, and to increase the efficiency of production facilities. Early weaning also facilitates group or batch weaning of piglets, which makes all-in all-out systems possible. This all-in all-out strategy benefits the producer by allowing facilities to be cleaned and disinfected between groups of farrowing sows, thus decreasing the possibility of disease transfer between animals.

While early weaning may increase the number of piglets overall, it can have a negative effect on the sow's reproductive performance. It is known that the weaning to estrus interval (WEI), weaning to service interval, and weaning to conception interval increase with a decrease in lactation length (Foxcroft et al. 1995). These intervals can all be counted as NPD's. However, in a production context, the increased WEI is usually offset by the increase in litters/sow/year, resulting in an economic benefit to the producer.

Weaning even earlier than 14 - 21 days, for example at 0-7 days of age, has been shown to further reduce conception rate, reduce litter size, increase the occurrence of cystic follicles, and increase early embryonic death. As a result, weaning at less than 14 days is not often used in production practice (Varley et al. 1985, Elliot et al. 1980). However, with the knowledge that early weaning at approximately 14 - 21 days can increase overall production, other aspects must be carefully examined and manipulated in an effort to offset the negative effects on the breeding sow resulting from early weaning.

Some of these factors include seasonality, nutrition, housing, and animal social interactions. These factors appear to be important in influencing the sow's reproductive potential and further, influencing the hormone profiles and patterns, thus altering the sow's performance via endocrine mechanisms. However, many of the endocrine mechanisms and the pathways through which they work remain unclear.

One of the most significant influences on reproductive performance in the domestic sow is seasonality. European wild boars, ancestors of today's domestic pigs, are seasonal breeders, with the females showing anestrus during the summer months (Kermabon et al. 1995). Seasonality can also be seen in domestic swine as a tendency to display summer infertility, which translates into economic loss (Kermabon et al. 1995,

Foxcroft et al. 1995). This summer, or seasonal infertility on commercial farms has been documented by numerous researchers and is characterized by: lowered ovarian activity, increased abortion rates, decreased conception and farrowing rates, irregular return to estrus after weaning, longer WEI, and delayed puberty in gilts.

Photoperiod duration, rather than ambient temperature, appears to be the main environmental factor responsible for this seasonality (Delcroix et al. 1990, Love et al. 1993, Peltoniemi et al. 1999). Increasing the light duration throughout the gestation period can increase the WEI (Kermabon et al. 1995). Taking these factors into consideration, it seems logical that a short day lighting regime in the barn could minimize WEI and maximize reproductive performance of sows. In the past, a long photoperiod tended to be used in most breeding barns. However, making use of sow's sensitivity to photoperiod should translate directly into economic gains for the industry.

Furthermore, a relationship between the actual hour of weaning relative to onset of lighting, and the onset of estrus has been suggested (Evans et al. 1996). Using a long-day light regime (14h light:10h dark) Evans et al. (1996) concluded that sows weaned early in the morning, before lights-on, demonstrate a hormone profile that optimizes insemination at 88 hours and 104 hours after weaning. These sows also began to display signs of estrus during daylight hours, when routine estrus checks are being made. It was further noted by Evans and colleagues that sows weaned just prior to, or after lights-out demonstrated a much different and presumably sub-optimal hormone profile and began to show signs of heat during the night, making accurate determination of onset of estrus unlikely.

The long photoperiod used by Evans and colleagues (1996) in their research (lights-on at 0600h and lights-off at 2000h) would appear to be contrary to the natural seasonal tendencies of sows, as better performance would be expected using a short day light program.

However, even under a long photoperiod, it is of interest to note that the largest difference in luteinizing hormone pulse frequencies and the time that they occurred was after the two weaning times of 0400h (2 hours before lights-on) and 1600h (4 hours before lights-off). These data indicate that the period directly following weaning may be important for subsequent LH levels and ovulation. Hormone changes, specifically luteinizing hormone, follicle stimulating hormone, estrogen, and progesterone play an important role in subsequent follicular development, ovulation rates, conception rates, and embryo survival rates (Armstrong et al. 1986, Smith et al. 1991, Love et al. 1993, Peltoneimi et al. 1991). All these components impact directly on the reproductive performance of the sow. It is not known what effect a light or dark period immediately after weaning would have on estrogen levels, LH activity, or estrus onset under a short day light regime. The relationship between photoperiod, time of weaning, and estrus onset remains unclear.

Effect of Lactation Length on Productivity

Early Weaning

Because the sow has a fixed gestation period of 114 days (102d-128d) (Hafez 1993), and generally remains in an anestrus state during lactation, other periods in the

sow's reproductive cycle must be manipulated in order to increase the number of litters per sow per year. Lactation length is the variable that is commonly reduced in an effort to increase the sow's economic return. One primary aim of reducing the lactation length, or weaning early, is to increase the frequency of farrowing and ultimately increase the number of pigs per sow per year.

Although economic returns may increase when early weaning is practiced, there are some negative effects associated with a short lactation length. These can include longer WEI and smaller litter size at the subsequent farrowing (Xue et al. 1993). In younger sows or sows in poor body condition at the time of weaning, this effect can be more pronounced. In both of these cases, the sow requires energy for the deposition of lean tissue growth or replenishment, at the expense of fat deposition (Clowes et al. 1994). Johnston et al. (1989) determined a negative correlation between body fat and WEI in primiparous sows. Other research has shown that sows with longer lactation lengths (3-6 weeks) had significantly larger litters (total born and born alive) in their subsequent farrowing when compared to sows with shorter lactation lengths (1-2 weeks) (Xue et al. 1993). However, it is important to note that sows with a shorter lactation tend to have longer WEI's but shorter *farrowing-to-farrowing intervals* (Xue et al. 1993). This shortened farrowing to farrowing interval translates directly into an increase in litters per year for the sow. And while a longer WEI is considered undesirable, overall economic returns of more litters/sow per year may be more advantageous to the producer.

Other Weaning Methods

Apart from early weaning at two to three weeks, other weaning methods employed in an effort to improve sow productivity include zero weaning and partial weaning. Zero weaning, or weaning at birth, has resulted in the occurrence of more pronounced problems and is not commonly used in commercial practice (as reviewed by Elliot et al. 1980). The negative effects are manifested in large increases in the duration of weaning to a fertile estrus, a reduction in subsequent litter size, and an increase in the incidence of cystic ovarian degeneration and cystic follicles (as reviewed by Elliot et al. 1980, Peters et al. 1969). Aside from any physiological effects, a great deal of time and effort must be put into raising piglets artificially from birth, which may simply not be feasible or cost effective in today's large commercial units.

In an effort to avoid problems associated with zero weaning, but to encourage return to estrus sooner than would be characteristic of an early wean schedule, partial weaning has been evaluated. The purpose of partial weaning is to induce the sow into estrus during lactation. By removing the piglets from the sow for a set time each day, the producer removes some of the suckling inhibition on estrus. Inhibition of estrus by lactation, due to suppressed gonadotropin release, decreases as lactation proceeds, and by removing the suckling stimulus responsible for maintaining lactational anestrus, partial weaning serves to speed up this process (Henderson et al. 1984). This practice has been met with mixed results. Newton et al. (1987) demonstrated that partial weaning (removal of sow from litter for 6 hours / day beginning at 20 days), plus boar exposure caused some multiparous but few primiparous sows to show lactational estrus before weaning at 28 days. Magnitude and duration of LH pulses appeared to be unaffected by partial

weaning when compared with profiles from control sows (Newton et al. 1987). Further, partial weaning significantly reduced the weight of the weaned litter for all parities, most likely due to the decreased suckling allowed for the piglets (Newton et al. 1987, Henderson et al. 1984). In other studies, partial weaning did not result in any sows demonstrating a lactational estrus, although it did significantly reduce the WEI (Henderson et al. 1984).

The benefits in using partial weaning are unclear and a definite advantage cannot be seen. While possible in a small production operation of approximately 100 sows or less, partial weaning would be extremely labour intensive and difficult in a large commercial operation. In addition to this, the negative effect on litter weight must also be considered.

Lactational Anestrus

After parturition, uterine involution and endometrial repair take place after approximately 20-21 days and the uterus prepares to sustain another successful gestation (Hafez, 1993). During lactation, the sow remains in a state of lactational anestrus (Stevenson et al. 1981). The ovaries remain relatively inactive for approximately 10 days following parturition (Varley and Foxcroft 1990). After this time, small follicles may begin to develop although none attains the size of a Graafian follicle (Varley and Foxcroft 1990).

Hormone actions during lactational anestrus

Endocrine events associated with piglet suckling act at the level of the sow's hypothalamus to block the pulsatile release of GnRH and thereby suppresse gonadotropin secretion (Newton et al. 1987, Delcroix et al. 1990, Sesti et al. 1993). The exact pathway through which this mechanism works is unknown (Newton et al. 1987, Sesti et al. 1993). In both primiparous and multiparous sows, circulating concentrations of LH and FSH in the blood are relatively low during the first week of lactation, but gradually increase after this time (Sesti et al. 1993, Newton et al. 1987, Stevenson et al. 1981).

This suppression of ovulation during the first week of lactation may not, however, be directly due to insufficient amounts of pituitary LH. Work done by Sesti and colleagues (1993) demonstrated the greatest suppression of LH secretion from the pituitary occurred on day seven of lactation, with a linear increase in LH secretion during the next 14 day period. However, the pituitary showed an increased response to GnRH on day 7 when challenged with exogenous GnRH. This indicates that the pituitary begins to store large amounts of LH throughout the first week of lactation. It would therefore appear that the basal secretions of GnRH during the first week of lactation are enough to stimulate the synthesis but not the secretion of LH.

Accompanying the increase in LH and FSH in the second and third week of lactation, an increase in GnRH along with an increased number of larger follicles and a coincident increase in serum estrogen were observed (Sesti et al. 1993). In addition to stimulating the synthesis of LH, GnRH may also be responsible for priming the anterior pituitary and increasing sensitivity to GnRH by upregulating receptors (Sesti et al. 1993). In contrast to LH, basal FSH does not appear to be under the control of hypothalamic

GnRH during lactation. It has been suggested that the secretion of FSH is under the control of an ovarian controlling factor, possibly inhibin (Sesti et al. 1993, Stevenson et al. 1981).

The steady increase in LH can be viewed as a progressive "escape" from the inhibitory effects of the preceding pregnancy and to the decrease in suckling intensity during later lactation (Shaw and Foxcroft 1985). The dysfunction of the estrogen positive feedback mechanism in early lactation is thought to be the result of prolonged exposure of the hypothalamic-pituitary axis to high levels of progesterone during gestation (Varley and Foxcroft 1990).

Secretion of estrogen and progesterone remained low throughout lactation until weaning (day 21) in primiparous sows (Sesti et al. 1993). However, in multiparous sows, basal secretions of estrogen rose from mid to late lactation, indicating that follicular development was greater in multiparous sows than primiparous sows during lactation.

Physiology of the Sow at the Time of Weaning and During the WEI

The corpora lutea of pregnancy begin to regress late in pregnancy, shortly before parturition, and this process continues until a few days into lactation (Varley et al. 1985). Uterine involution and repair begins after farrowing and is complete by day 21 post partum (Palmer et al. 1965).

During reproductive life, mammalian ovaries have a pool of primordial follicles each consisting of an oocyte arrested in prophase I of meiosis (Fortune 1994). Once the follicle begins to grow it meets one of two fates: it ovulates or undergoes atresia. Few

follicles that develop actually ovulate as most undergo atresia. Follicular growth can occur readily in the presence of normal basal concentrations of gonadotropins, but only up to a point (Fortune 1994). After this point, only follicles 'selected' to ovulate will receive additional signals, allowing continued growth, development, and ovulation (Fortune 1994).

Prior to the preovulatory surge of gonadotropins, and thus ovulation, a rise in estradiol secretion and synthesis is seen (Conley et al. 1994, Ash et al. 1975) This rise in estrogen serves as a positive feedback stimulus to gonadotropin secretion. Subsequently, the initial rise in pre-ovulatory LH precedes the rapid decline in estrogen secretion. Peak levels of estrogen are usually seen approximately 8-15 hours before peak levels of LH are observed (Foxcroft and van de Weil 1982). Compared with other mammalian species, the LH surge in sows is relatively moderate in magnitude increase, but this elevation occurs over a longer period of time, as demonstrated by Van de Weil and colleagues (1981), who compared maximum LH levels associated with tonic episodic secretion during the luteal phase of the cycle (approximately 3ng/ml) and the maximum levels of LH seen in the LH surge (approximately 6ng/ml). FSH response to this positive estrogen feedback is variable (Foxcroft and van de Weil 1982).

Weaning after 3 weeks of lactation in multiparous (Shaw and Foxcroft 1985) and primiparous (Foxcroft et al. 1987) sows normally results in an immediate increase in ovarian activity and an early and relatively synchronous return to estrus. In the sow herd, each animal usually exhibits estrus approximately 4-8 days after weaning. A WEI of greater than 10 days is usually viewed as problematic from a managerial standpoint (Killen et al. 1992). This 4-8 day period is similar to the length of the follicular phase of

the sow's estrous cycle, which might suggest that the follicular recruitment for preovulatory growth occurs immediately after weaning (Kermabon et al. 1995). Development of large follicles are inhibited during pregnancy (Simoneau 1988) and lactation (Stevenson et al. 1981).

At the time of weaning, an increase in LH pulsatility is seen (Kermabon et al. 1995, Stevenson et al. 1981). The hypothalamic content of GnRH shows a significant increase within 60 hours of weaning, although the relationship between this increase in content and the actual release of GnRH and thus FSH and LH is unclear (as reviewed by G. Foxcroft 1985). This increase in gonadotropins acts as a stimulator for follicular recruitment for subsequent ovulation (Killen et al. 1992, Foxcroft et al. 1987, Foxcroft et al. 1995, Kermabon et al. 1995). Mean LH concentrations generally remain low immediately after weaning, but show a slow, steady increase with an abrupt increase on the day before estrus (Shaw and Foxcroft 1985, Stevenson et al. 1980, Ash et al. 1975). These high LH levels decrease and remain low during the early part of the subsequent pregnancy (Ash et al. 1975). A graph illustrating a typical endocrine profile of a WEI of approximately four days is shown in Figure 1.

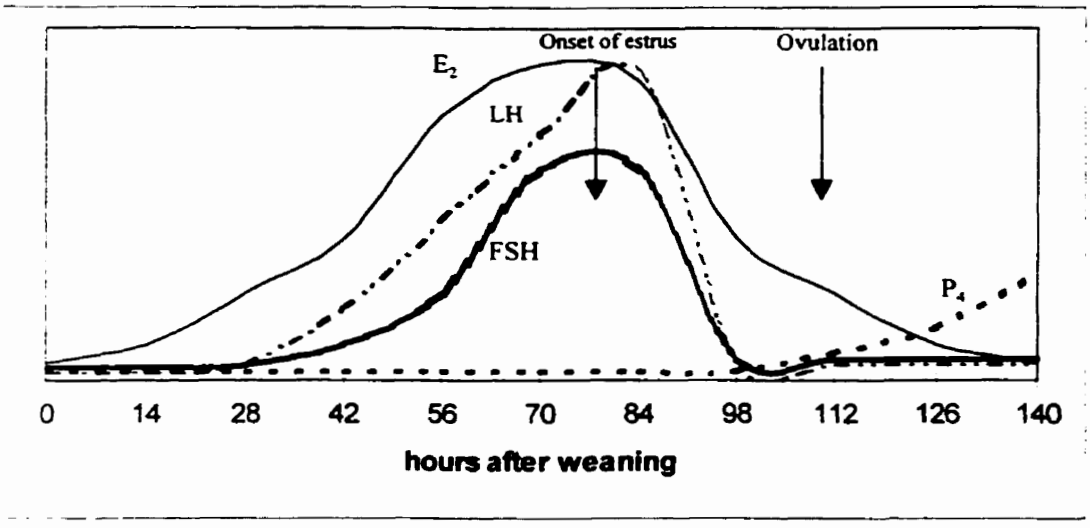

Figure 1. Diagramatic representation of changes in estradiol (E_2), LH, FSH, and progesterone (P_4) following weaning. (adapted from Hafez 1993)

Immediately after weaning (within 6 hours), follicular growth and accompanying steroid changes occur rapidly (Killen et al. 1992). During the follicular phase of the estrous cycle, the follicle population changes. The number of follicles >3mm in diameter (medium and large) decreases (Clark et al. 1982). Similarly, a reduction of 5-10 mm follicles occurs in sows during the first 4- 6 days after weaning, however a majority of the largest follicles present at 48-72 hours after weaning continues to develop and ovulate (Killen et al. 1992). It should be noted that classification of follicles based on size is a convenient way to identify development, but their biosynthetic activity varies with physiological status of the sow and between follicles from the same ovary (Killen et al. 1992). A large follicle on an ovary may not be the most active in synthesizing estrogen, and may in fact be a candidate for atresia (Killen et al. 1992).

Variability in porcine follicular development between animals cannot be adequately accounted for by changing levels of LH and FSH (Killen et al. 1992).). During lactation, the neuroendocrine response to suckling has a clear inhibitory effect on gonadotropin secretion (Foxcroft et al. 1995). The subsequent lack of pulsatile LH release results in the arrest of follicular development during lactation (Foxcroft et al. 1995). It has been suggested that in sheep, an increase in pulsatile LH release is a necessity for final follicular growth and maturation (Killen et al. 1992). Further, in reference to WEI, the LH pulse frequency and mean minimum concentrations were greater in sows showing estrus within 4 days of weaning, but pulsatility and mean basal values of LH could not be consistently correlated with the time required for return to estrus (Shaw and Foxcroft 1985). It is possible that variations in LH response to weaning would result in a variation of the WEI.

These varied patterns of LH pulsatility after weaning might be attributed to the state of ovarian activity at weaning. A relationship between lactational LH secretion and subsequent ovarian development has been suggested (Foxcroft 1987, Shaw and Foxcroft 1985). That is, at low levels estrogen is considered part of a negative feedback mechanism for pulsatile LH release, and sows possessing ovarian follicles at a greater state of activity at the time of weaning would likely result in elevated plasma estrogen levels suitable to augment the weaning associated rise in LH with a consequent increase in mean and basal LH levels (Shaw and Foxcroft 1985). However, the exact mechanism involved in the separation of the negative and positive feedback effects of estrogen is not known.

Characteristics of the pre-ovulatory LH surge do not appear to be affected by the interval from weaning to LH peak, although an increase in lactation length is associated with an increase in the magnitude of the LH surge (Edwards and Foxcroft 1983). This would indicate the occurrence of a 'recovery' for the estrogen positive feedback mechanism during lactation (Edwards and Foxcroft 1983). However, recovery of pituitary response to GnRH is not a component of this recovery phase of the positive feedback mechanism, as similar LH responses to GnRH treatment have been seen throughout lactation (as reviewed by Foxcroft 1986).

According to the literature, changes in post-weaning FSH are not consistent. In contrast to the steady increase in LH after weaning, levels of FSH do not change consistently (Foxcroft et al. 1987). Edwards and Foxcroft (1983) noted inconsistent rises in FSH levels after weaning. During the pre-weaning period, there is a negative correlation between basal LH concentrations and mean plasma FSH concentrations (Foxcroft et al. 1987). This would suggest independent control of FSH and LH. Shaw and Foxcroft et al. (1985) saw a post-weaning increase in FSH, which led to the suggestion that lactation must have some sort of inhibitory effects on FSH secretion. Concentrations of FSH after weaning, similar to LH, could not be correlated to the length of the WEI. Shaw and Foxcroft (1985) demonstrated a positive correlation between FSH levels at weaning and ovulation rate. However, it appears that the post-weaning rise in FSH is not a prerequisite for follicular growth and ovulation, as a number of sows in this study that failed to show an increase in post-weaning FSH ovulated by day 3 and 6 after weaning (Shaw and Foxcroft 1985). Therefore, lactational levels of FSH must be

adequate to activate and maintain ovarian function in preparation for subsequent ovulations.

WEI

Many factors influence the duration of estrus including genetic background, breed, stress, parity, season, boar stimulation, all to varying degrees (Kemp et al. 1997, Steverink et al. 1999). However, it is the WEI that appears to have a consistent influence, regardless of additional factors. Considerable research has shown a direct correlation between the WEI and duration of estrus. It can be said that in general, the longer the WEI, the shorter the duration of estrus becomes, even in the presence of a boar (Weitz et al. 1994, Kemp et al. 1997, Steverink et al. 1999). A long WEI resulting in a short duration of estrus leaves the producer at a disadvantage, as a short estrus duration increases the chance that the sow may be missed in routine heat check after she is weaned.

Ovulation occurs at approximately 70% of the estrus period (Evans et al. 1996, Soede et al. 1994). Duration of ovulation lasts between 1 and 3 hours (Kemp et al. 1997). Optimal insemination time occurs between 0-24 hours before ovulation and inseminating outside of this range results in a decreased fertilization rate (Kemp et al. 1997, Soede et al. 1995a). However, the high variation in estrus duration subsequently results in high variability of the interval for the onset of estrus to ovulation. Therefore, onset of estrus is not a good predictor of ovulation. Sows with longer WEIs will show a shorter duration of estrus and simply ovulate earlier after the onset of estrus than those

sows with shorter WEIs and longer estrus duration. Sows with shorter estrus duration should therefore be bred earlier after onset of estrus than those sows demonstrating a longer estrus duration.

In practice, because it is impossible to know how long the estrus period will last, insemination is usually done at the first signs of standing heat and then at a regular intervals after, in an attempt to ensure optimal fertilization. Previous work has demonstrated when first insemination takes place more than 24 hours before ovulation, or after ovulation has taken place, fertilization results are poor (Soede et al. 1995b). It is assumed that the decrease in fertilization rate when insemination occurs after ovulation is due to the limited lifespan of the oocytes as well as the time needed for the sperm cells to capacitate and reach the fertilization site (Soede et al. 1995a). Further, it appears that after ovulation, the regulation of spermatozoa moving from the uterus to the fertilization site is less effective, allowing larger number of sperm to reach the oocyte at the same time, and thus resulting in a higher rate of polyspermic fertilization (as reviewed by Soede et al. 1995a). Polyspermic embryos degenerate early in development (Hunter et al. 1967). However, recent research has demonstrated that inseminating sows for a second time within 5 hours after ovulation had no negative effects on fertilization rate, and in fact, showed better fertilization rates and normal embryo development than in those sows inseminated only once before ovulation (Soede et al. 1995a). Further, Soede and colleagues (1995a) noted that much of the previous research had been done under unnatural conditions such as hormone therapy or oviductal inseminations. They proposed that under natural conditions, polyspermic fertilization may not occur as readily as

assumed and reduced fertilization rates of those sows inseminated for the first time after ovulation may simply be due to lack of fertilization and not degenerating embryos.

Soede et al. (1994) demonstrated that the timing of the preovulatory LH surge, ovulation. and increase in progesterone levels are strongly linked to each other, regardless of the length of the WEI. Ovulation occurs consistently at approximately 30 hours after the LH surge (Soede et al. 1994). It should also be noted that sows with higher basal LH concentrations show higher estradiol concentrations (Soede et al. 1994). These higher estradiol concentrations are associated with a shorter duration of estrus and with a longer interval between weaning and ovulation (Soede et al. 1994). Finally, a rise in peripheral blood progesterone of 1ng/ml above basal concentrations occurs approximately 13 hours after ovulation (Soede et al. 1994).

. Studies have proven that there is a negative correlation between WEI and subsequent litter size and farrowing rate, independent of parity and breed (Vesseur et al. 1994. Kemp et al. 1996). Data presented by Kemp et al. (1996) suggest that the decrease in farrowing rate seen in sows with a longer WEI and a shorter estrus duration probably results from a greater number of sows that are actually inseminated too late. Steverink et al. (1999) found complimentary results when examining farrowing rates. Farms that had the greatest farrowing rates and litter size had a longer average duration of estrus, regardless of parity effects. Farrowing rates consistently decreased with increasing WEI.

It is important to note, however, that the data presented by Kemp et al. (1996) also demonstrated that sows with increased WEI had a higher embryo mortality rate after day 5 of pregnancy. While an increased embryo mortality rate may have resulted from a

suboptimal fertilization time, it is possible that the WEI may also play a role in decreased farrowing rates and litter size through other mechanisms.

Additionally, beyond the overall pattern of longer WEI resulting in shorter estrus duration, Steverink and colleagues (1999) determined from their data that gilts and repeat breeders had a significantly shorter duration of estrus than sows after weaning. Parity one and two sows further displayed a shorter duration of estrus than parity three or higher. While other researchers did not find any parity effects, by direct comparisons of older and younger sows, age does seem to have an effect on duration of estrus.

Embryo Survival

There does not appear to be a relationship between the magnitude of preovulatory LH and FSH surges and subsequent fertility, however it has been suggested that differences in patterns of luteinization and thus progesterone secretion have an effect on embryo survival (Foxcroft et al. 1995, Soede et al. 1994). Embryo survival is related to the interval between the time of the peak estradiol concentration and the peak LH concentration and to the interval between the occurrence of the peak estradiol concentration and the rise in progesterone concentration - the longer these intervals, the lower the embryo survival (Soede et al. 1994). After estrus and ovulation, there is a sharp increase in plasma progesterone secreted from the newly formed corpora lutea (Ash et al. 1975). The subsequent high progesterone level produced by the CL is responsible for maintenance of pregnancy. It is important to note that in the sow, the placenta contributes to the production of progesterone during late pregnancy, but is not sufficient

to sustain pregnancy. Ovariectomy in the sow during pregnancy results in abortion in 2 - 3 days (Hafez 1993).

Concentrations of steroid hormones at the time of weaning and ovulation appear to have an effect on subsequent embryo survival. In general, sows with higher levels of circulating estrogens have lower embryo survival rate (Varley et al. 1984). Suckled sows weaned after a lactation of 10 -20 days are reported to have higher levels of estrogen at the time of weaning when compared to sows weaned after a longer lactation length (Varley and Foxcroft 1990). This may in part contribute to the lower litter sizes seen in early weaned sows.

The reduction of litter size characteristic of early weaned pigs has been attributed to a possible decrease in ovulation rate, but more importantly, to a change in embryo mortality. Varley and colleagues (1976) observed no significant differences in ovulation rate between sows that were weaned at 7, 21, or 42 days. However, a significant difference in embryo loss by day 25 of pregnancy was observed. Sows weaned at 42 days had an embryo loss of 17.3% as compared to sows weaned at 7 days which had an embryo loss of 40.4%. Sows weaned at 21 days had an embryo loss of 35.2%. This indicates that the major limiting factor must be the inability of embryos from early weaned sows to survive at the early stages of pregnancy (Varley et al. 1976).

The insemination to ovulation period also has an effect on embryo viability. Sows with potential litters that have had a low fertilization rate have slightly retarded embryo growth and a higher variation in embryonic development as compared to sows with full or high fertilization (Kemp et al. 1997). However, the relationship between this variation in embryonic development and potential subsequent embryonic mortality has yet to be

clearly defined (Kemp et al. 1997). Sows that display a very short estrus duration and are subsequently not detected early enough and inseminated too late may demonstrate compromised embryonic growth and development.

Seasonality

European wild boar

The domestic pig originally evolved from the wild boar. The European wild boar is a seasonal short day breeder, and this seasonality can be still be seen in today's domestic breeds (Delcroix et al. 1990). European wild boars produce one litter per year, usually born in the spring months (Delcroix et al. 1990, Claus and Weiler 1985). As documented by Delcroix et al. 1990, breeding occurs in late autumn to early winter. Boars are for the most part solitary and do not remain with the sows during the year, outside of the breeding season. It is of interest to note however, that the commencement of the breeding season in the fall/winter depends on feed supply availability. A plentiful food supply allows early breeding activity and may allow the sow to show a second breeding season in the spring. After farrowing, the sow will remain in anestrous throughout the summer and early fall until the subsequent breeding season. Weaning of the litter is gradual and usually takes 3 months. Early removal or death of a litter in the sow can allow her to return to estrus and produce two litters per year (Delcroix et al. 1990).

Although today's domestic pig is considered to be genetically different from the wild boar. they are still essential short-day breeders. Management practices used to get

the domestic sow to produce two or more litters per year are based on factors that allow the wild boar to produce two litters per year. That is, today's production systems employ early weaning, boar exposure, and a continuous supply of high quality nutrition.

Effect of Season on Productivity

The seasonal anestrus and infertility characteristic of the wild boar is still seen in the domestic sow and is a major economic problem. Seasonal infertility during the summer months and into early fall results in a number of problems including suppressed ovulation rates, decreased conception and farrowing rates, irregular returns to estrus, increased abortions (referred to as autumn abortions), longer WEI, reduced litter sizes, and delayed puberty in gilts. All of these result in a direct economic cost to the producer.

It is considered that the long photoperiod, independent of environmental temperature, is responsible for this decrease (Delcroix et al. 1990, Love et al. 1993, Peltoneimi et al. 1999). Late summer and early autumn consistently show the lowest values for sow reproductive performance.

A significantly higher rate of rebreeding occurs throughout August until November (Claus and Weiler 1985, Smith et al. 1991, Peltoneimi et al. 1999). Farrowing rates also follow this pattern. Highest farrowing rates were found from November to April, while the worst months were August and September (Claus and Weiler 1985, Peltoneimi et al. 1999, Smith et al. 1991).

WEI increases during the summer months when sows show lowered ovarian activity (Claus and Weiler 1985, Smith et al. 1991). Xue and colleagues (1994) further demonstrated that sows that were weaned in June, July, or August, had longer WEIs and a

lower percentage of sows returning to estrus within 6 days following weaning than sows weaned in November, December, or January.

The highest incidences of abortions in sows occur in September through October, hence the term autumn abortion syndrome, mainly in those sows that were mated between June and September (Claus and Weiler 1985, Smith et al. 1991). Implantation of the pig embryo begins on day 13 and attachment is completed across the trophoblastic surface between day 18 and 24 (Hafez et al.). If all the embryos die after implantation but before skeletal mineralization, then the female will have a delayed or irregular return to estrus (Xue et al. 1994). Irregular returns to estrus in July and August are approximately 2 times higher as compared to sows in November and December (Xue et al. 1994). These data suggest that the increased number of sows returning to estrus, at both regular and irregular intervals, could be the result of a terminated early pregnancy during the summer months. The increased abortions in the fall by sows bred in the summer may be sows experiencing a delay in the same mechanism that causes early pregnancy termination in the summer months.

Litter size and weaning weight are also affected by season. Following the pattern of increased conception rates during the winter months, litter size is significantly larger following conceptions in November, December, and January, as compared to conceptions in July and August (Xue et al. 1994). The 21-day weaning weights of litters farrowed in the winter months were significantly heavier than litters farrowed in July or August (Xue et al. 1994). It was suggested, however, that this reduction in weaning weight was likely due to a decrease in milk production by the sow as a result of suppressed appetite under warmer temperatures.

Effect of Seasonality on Endocrine Mechanisms

Gonadotropins

The suboptimal functioning of the ovaries characteristic of cyclic sows during the summer months is a result of altered endocrine activity (Peltoniemi et al. 1997a, Love et al. 1993, Smith et al. 1991, Armstrong and Britt 1986). Gonadotropins play a large role in this change and it has been well documented that season affects gonadotropin secretion and action in sows (Peltoniemi et al. 1997a, Love et al. 1993). However, the literature on the effects of seasonal changes on gonadotropins is for the most part unclear.

Overall mean basal concentrations of LH have been reported as higher in the summer/early fall compared to winter/spring (Peltoniemi et al. 1997a, Love et al. 1993). Smith and colleagues (1991) saw lower mean serum LH concentrations in the spring and summer than in fall and winter, with the highest concentrations of LH seen in the fall. Armstrong and Britt (1986), and Kermabon et al. (1995) saw lower LH concentrations in sows shortly after weaning in summer as compared to winter. Thus, it appears that an increase in mean basal concentration of LH tends to coincide with the approximate onset of fall, although a consistent pattern has not been established.

Further, during the winter months, pulses of LH appear to increase in pulse frequency (Peltoniemi et al. 1997a, Peacock et al. 1990a, Paterson 1992) and maintain a regular shape and higher amplitude (Peacock et al. 1990a, Paterson et al. 1992) when compared with low and irregular baseline concentrations of LH during the summer

(Peacock et al. 1990a, Paterson et al. 1992). On the other hand, similar pulse frequency and amplitude throughout the year has been documented (Love et al. 1993, Smith et al. 1991). The mechanisms controlling these differing pulsatile patterns remain unclear.

Logically, one might expect lowest LH levels during the summer months, paralleling the suppressed reproductive activity characteristic of this time. The delayed estrus characteristic of summer months may be in part due to insufficient LH release (and thus insufficient follicular recruitment) after weaning. However, given the inconsistent findings of the research, one cannot confidently link low LH levels as the main causative agent of seasonal infertility.

The effect of photoperiod on FSH has not been investigated as thoroughly. Overall, mean plasma concentrations of FSH do not seem to be affected by photoperiod in lactating sows (Prunier et al. 1994, Kermabon et al. 1995).

Effect of LH on Pregnancy Maintenance

Although seasonal variation of LH secretion and pulsatility has been documented, the effect of these variations on early pregnancy and CL maintenance remains unclear (Peltoniemi et al. 1997a). During early pregnancy, a total block of gonadotropins, or suppression of LH to basal levels, with no pulses before day 30, will result in abortion (Peltoneimi et al. 1997a, Peltoneimi et al. 1997b). Thus it seems that there is some need for gonadotropin pulses for maintenance of pregnancy, as inadequate pituitary support has been suggested as the primary mechanism of seasonal abortions and disruption of early pregnancy causing irregular return to estrus (Peltoniemi et al. 1997b).

LH Response to Estrogen

Changes in the ability of the hypothalamus and thus the pituitary to respond to estrogen during the summer months has been well documented. During the summer months the ability of estrogen to elicit a LH surge is diminished (Smith et al. 1991, Cox et al. 1986). There is also an increased sensitivity to the negative feedback mechanism of estradiol on LH release during anestrous (Cox et al. 1986, Smith et al. 1991). In other words, low circulating levels of estradiol easily suppress LH release at the pituitary level. Armstrong et al. (1986) documented transient increases in estradiol levels that failed to trigger estrus or cause an LH surge in weaned sows during the summer months. Insufficient LH release during the summer months (Smith et al. 1991), along with an increased threshold required to trigger the positive feedback mechanism of estrogen on LH (Armstrong et al. 1986) could result in a higher occurrence of anestrus, failure to stimulate follicular maturation, and insufficient production of estrogen to produce estrus, the preovulatory surge, and thus ovulation. Furthermore, the high incidence of autumn abortions, could be in part due to the inability of low LH concentrations during the summer months to provide sufficient support for the developing CL during early pregnancy, thus resulting in insufficient progesterone and later abortion (Smith et al. 1991). Throughout gestation, maintenance of the CL is essential for pregnancy in the sow.

Estradiol concentrations rise with follicular growth 2-4 days after weaning (Cox et al. 1986). This estrogen release is integral for the release of preovulatory gonadotropins, ovulation, and behavioral display of estrus. A decreased estrus response to estradiol during the summer months is coupled with the observation that this decrease is not

associated with ambient temperature, indicating photoperiod as the key factor in this change (Cox et al. 1986). During early fall, after the long photoperiod of the summer, it appears that the sows are more sensitive to the negative feedback of estrogen on LH release than the positive feedback mechanisms (Cox et al. 1986).

In a normal cycling sow, suppressive effects of estradiol on LH act at the hypothalamic level by suppressing GnRH release. During the summer months, not only does the E2 work at the hypothalamic level, it also acts directly on the pituitary resulting in a diminished response to GnRH (Smith et al. 1991). An increased metabolic clearance of estrogen is also seen in sows exposed to long photoperiods (Armstrong et al. 1986). This seasonal change in endocrine regulation may contribute to the seasonal reproductive patterns seen in sows.

Concentrations of progesterone in plasma are lower in the summer and early fall, when compared to spring and winter months (Love et al. 1993). It has been suggested that these lower progesterone concentrations may be due to an increased rate of clearance from the blood stream, as opposed to a decreased rate of secretion (Love et al. 1993), similar to the increased rate of clearance of estrogens suggested by Armstrong et al. (1986). Thus, it appears that the long photoperiod associated with the summer months is a causative factor in removal of steroid hormone at a faster rate from the blood. It may be hypothesized that the increased rate of removal of both estrogen and progesterone could be in part responsible for decreased reproductive efficiency, and in reference to progesterone, an increase in rate of abortions.

Melatonin Control of Seasonality

It is generally accepted that the regulation of seasonality by an animal is mediated through melatonin (Love et al. 1993 Paterson et al. 1992, Armstrong et al. 1988). How this melatonin works to influence hormone secretion from the hypopophseal-pitiutary-ovarian axis in swine is unclear. In general it can be said that plasma melatonin levels increase during the dark phase or scotoperiod. Work done in sheep, which are short day breeders, has demonstrated high concentrations of melatonin during the dark hours (as reviewed by Love et al. 1993). These high concentrations reduce the negative feedback of estradiol on GnRH secretion which then allows an LH surge and ovulation (as reviewed by Love et al. 1993).

In contrast to these data, Peacock et al. (1990b) noted lowest plasma melatonin concentrations occurred in sows during the winter months. Based on the knowledge that plasma melatonin levels increase during the scotoperiod, higher melatonin levels would be expected to occur during the winter months- at a time when the dark phase is the dominant phase. In sheep, it has been demonstrated that melatonin implants can stimulate reproductive activity under long day photoperiods, however, it does not seem to be the case in swine (Paterson et al. 1992). Melatonin implants given to gilts kept under a long-day photoperiod did not prevent the seasonal inhibition of puberty seen in swine (Paterson et al. 1992). Furthermore, melatonin implants in sows had an adverse effect on farrowing rates (as reviewed by Love et al. 1993). There are unusually high concentrations of plasma melatonin found in early pregnant sows during summer and early fall (as reviewed by Love et al. 1993). It has been suggested that these high levels

could have an negative effect on pregnancy maintenance (Love et al. 1993). Thus, the role of melatonin in regulating seasonality in swine is not clear, and it appears that there are numerous other mechanisms contributing to the seasonal regulation.

One of these mechanisms is the endogenous opioid system which melatonin has been shown to influence (Love et al. 1993). The endogenous opioid system seems to be important in controlling hormones secreted by the adenohypophysis, by affecting the steroid dependent feedback mechanism of LH (Love et al. 1993). They have been further implicated indirectly as a possible mediator of the suppressive effects of suckling on LH (Armstrong et al. 1988). B-endorphin decreases LH secretion in pigs, while administration of naloxone, an opioid antagonist, causes a dramatic increase of LH and prolactin when in the presence of progesterone (Love et al. 1993). This illustrates an indirect pathway in which melatonin may affect LH secretion.

Light and Dark Cycles

Aside from overall photoperiod, hormone patterns differ during the actual light and dark phases of a 24-hour period. When challenged with exogenous estrogen, gilts kept under a 14L:10D photoperiod regimen were found to have altered LH secretion during the light phase as compared to the dark phase (Evans et al. 1994). Estrogen administered during the dark phase, resulted in a single high peak of LH, while estrogen administered during the light phase, resulted in a biphasic pattern of LH with low peaks.

It has be shown that the majority of spontaneous LH surges seem to occur during the night and early morning hours, or the dark phase of the light/dark cycle independent

of the light:dark ratio (Evans et al. 1994). Thus, it appears that there may be a relationship between the light-dark cycle and the release of estrogen, directly affecting the release of LH necessary for ovulation. In sows kept under a long-day photoperiod (14L:10D), the time of day that the sows are weaned may influence the timing of the LH pulses. Evans and colleagues (1996) reported that weaning sows in the morning, 2 hours before lights-on, resulted in LH peaks occurring in a cluster within an 26 hour period, with the majority of peaks (67%) occurring mainly during the daylight hours. Sows weaned in the afternoon, 2 hours before the lights-out period, resulted in the majority of the peaks occurring during the dark phase (90%) and tended to be more spread out over a 56 hour period. Thus, it appears that LH activity may be manipulated by the time of day that the sows are weaned. It is not known how a short-day photoperiod regime would influence this LH activity, or what effect this altered LH activity might have on subsequent litter performance. Furthermore, the effect of weaning times may be further altered by keeping the sows under a short-day photoperiod.

Influence of Temperature on Reproductive Performance of the Sow

Although it is photoperiod that is considered to be responsible for the seasonal anestrous and diminished reproductive capacity during the summer months, temperature also plays a role (Prunier et al. 1994). Higher lactational live weight losses are usually seen in the summer months, most likely due to higher rates of mobilization of the sow's body reserves during summer (Prunier et al. 1994). This difference may be attributed to a decrease in appetite and feed intake under high ambient temperatures. As stated

previously, sows weaned with high losses of body fat and weight will have a tendency for longer WEI.

Prunier and colleagues (1994) compared similar sized litters born in January and July and reported high ambient temperatures during July increased prenatal growth up to 15%, but decreased growth rate after birth. The reason for this phenomenon is not known. The decrease in weaning weight is probably due to the decreased lactation of the sow as influenced by a decreased appetite under high ambient temperatures. Prunier and colleagues (1994) also noted that a decrease in photoperiod while maintaining high ambient temperatures was not enough to restore a good WEI. This however, may be due to a poor body condition score at the time of weaning, resulting in a longer delay in return to estrus.

Elevated environmental temperatures are related to suppressed gonadotropin release (Smith et al. 1991, Prunier et al. 1994). While temperature does not appear to have any effect on FSH, LH pulsatility is inhibited by high ambient temperatures (Prunier et al. 1994). Under high ambient temperatures which can be considered a stressor, plasma cortisol levels increase (as reviewed by Prunier et al. 1994). It has been established that chronically high cortisol levels block GnRH and LH secretion (Booth et al. 1990), as well as decreasing the responsiveness of the pituitary to GnRH (Varley, 1994), offering a possible mechanism through which high temperature may act to inhibit reprodutive performance.

While the literature remains somewhat unclear as to the exact role of temperature on reproductive performance, it is likely that the change in gonadotropins is influenced by a combination of photoperiod, temperature, and to a degree, the sow's body condition.

High ambient temperatures seem to be most important during lactation, affecting appetite, and thus loss of body condition during this period (Prunier et al. 1994). This loss of body condition may play a large part in subsequent rebreeding fertility problems associated with the summer months.

Nutritional Influence on Reproductive Productivity

Nutrition

It has been well documented that delayed post-weaning estrus occurs more frequently in lean sows than in moderately fat sows (Johnston et al. 1989). It is of utmost importance that sows show a steady increase in feed intake immediately after parturition until the time of weaning. Large losses of body weight and fat during lactation are positively correlated with a delayed post-weaning estrus (Johnston et al. 1989).

The nutritional status of the sow can have major effects on ovarian activity (Foxcroft 1995). A deprivation in nutrition during lactation has a direct effect on LH secretion and pulsatility, thus affecting the sow's fertility after weaning (Foxcroft et al. 1995). It is the action of gonadotropins just before the recruitment of follicles into the follicular phase which is a major determining factor in the sow's subsequent reproductive performance. The pool of follicles available for ovulation and luteinization may be reduced under poor nutritional conditions during lactation (Foxcroft et al. 1995).

LH concentration and pulse frequency are gradually restored in primiparous sows during lactation. Sows that displayed a prolonged period between weaning and estrus usually had a decreased level of plasma LH (Kemp et al. 1995). The timing of post-

weaning estrus may have more to do with ME intake during lactation than body fat (Johnston et al. 1989). Furthermore, it has been suggested that the dietary energy source can influence energy production in gilts and stimulate the release of LH and progesterone (Kemp et al. 1995). Various dietary ingredients have been examined for this purpose, with mixed results. For example, adding fat to the diet does not have an effect on milk yield, sow weight loss during lactation, or weaning weight of the litter (Kemp et al. 1995). Similarly, other studies have been unable to show a clear beneficial effect of a high energy feeding level directly on gonadotropin secretion (Peltoniemi et al. 1999). While utilization of individual dietary energy sources has been met with varied results, suppression of dietary energy intake and reduction of weight and body fat loss over the course of lactation consistently diminishes subsequent reproductive potential of the sow (Peltoneimi et al. 1999). Sows that are weaned with a high loss of weight and body condition will demonstrate a longer WEI. This loss must be avoided.

Nutrition Interacting with Photoperiod

There is a relationship between nutrient intake and photoperiod. It has been suggested that ad libitum feeding in swine may counter the inhibitory photoperiod effect on puberty (as reviewed by Love et al. 1993). This interaction has been shown in the rat, which is considered to be insensitive to photoperiod. Feed restriction causes the rat to become responsive to photoperiod (as reviewed by Love et al. 1993). In large scale commercial swine operations, it has been shown that the negative effects of seasonality on pregnancy can be reduced by giving the sows a relative abundance of feed during the

first 4 weeks of pregnancy. Autumn abortions in swine have seen to be decreased by increasing the feed level in the fall, although the occurrence of abortions is not correlated with body condition (as reviewed by Love et al. 1993). The wild boar will also show a second breeding season with an abundance of feed (Delcroix et al. 1990). Thus, it appears that a high plane of nutrition can counter some of the inhibitory and detrimental effects of photoperiod.

Other Management Factors Affecting Reproductive Performance

It has been reported that individual crates for the mated sow (gestation crates) reduce the number of autumn abortions (Love et al. 1993). Furthermore, when sows are housed in groups, those sows housed in groups of 5-6 animals seemed less affected by seasonal infertility problems, such as reduced farrowing rates than those sows housed in larger groups (Love et al. 1993). Peltoniemi et al. (1999) found a clear seasonal reduction in farrowing rates during the summer months, but no evidence of a seasonal difference between sows housed in groups and sows housed in individual stalls. However, a significantly greater proportion of group-housed sows returned to estrus after mating, especially during the seasonal infertility period. This may be due a sow-to-sow or alpha-female type interaction to determine which sows abort and which sows remain pregnant (Peltoniemi et al. 1999). It should also be noted that the reduced farrowing rates seen in large groups may be partially attributed to management techniques. The possibility of missing a sows estrus is greatly increased when sows are housed in large groups as estrus detection becomes more difficult. Thus, while it seems that housing type may have a

significant effect on reproductive performance, the effects of management that goes along with each housing type must also be considered.

Sow-to-sow interaction is also important in synchronizing estrus in swine. In most species, synchronization of the female estrous cycle results from exposure to a male. However, in the pig, synchronization of ovarian activity in the sow appears to be synchronized in the presence or absence of a boar (Delcroix et al. 1990). Gilts housed in large groups of 10 or more will tend to reach puberty at the expected time, while gilts housed in groups of 2-3 animals will show a delayed puberty (Senger 1997). Boar exposure on either of these groups will result in an early onset of puberty (Senger 1997, Kingsbury et al. 1993). The main mechanism through which this is achieved is via olfactory stimulus (Kingsbury et al. 1993).

Conclusion

Early weaning has become a standard production practice throughout the industry. While increasing overall production in terms of piglets per sow per year, early weaning decreases the sow's reproductive performance. These negative effects may be manifested as longer WEI's, decreases in litter size, reduction of conception rate, and increases in embryonic death. To offset these negative effects, the endocrine mechanisms thought to be responsible for these changes have been examined in great detail. Further, other aspects of production have been manipulated in an attempt to improve the reproductive potential of the breeding sow.

It is generally agreed that the shorter the lactation length, the longer the WEI. During lactation, gonadotropin release is inhibited, mainly by the suckling stimulus of the piglets. Immediately after weaning, an increase in gonadotropin secretion followed by follicular development and accompanying steroid changes occurs. These changes prepare the sow for subsequent estrus, ovulation, and pregnancy. They include; pulsatile and mean basal concentrations of LH and FSH, LH surge magnitude and duration, estradiol synthesis and concentrations, estradiol surge magnitude and duration, and progesterone concentrations during early pregnancy. These hormones, working together, are integral in influencing folliculogenisis, ovulation rates, conception rates, duration of estrus, embryo survival, and pregnancy maintenance.

However, compounding the effect of lactation length on the WEI, are other factors such as season, light and dark cycles, nutrition and other management factors. The sow's sensitivity to photoperiod is one of the most important factors and can be seen throughout the industry as a seasonal decrease in reproductive performance. Not only is it apparent that sows are short-day breeders, but research has suggested that actual light and dark cycles are important. It has been reported that endocrine profiles can be manipulated through the use of timed weaning relative to light-dark cycles. However, the relationship between photoperiod, time of weaning, estrus onset and subsequent reproductive performance remains unclear.

CHAPTER 3

MATERIALS AND METHODS

Animals

A total of 84 Cotswold sows were used in two trials: 43 in trial 1 conducted in June (summer) and 41 in trial 2 conducted in November (fall). Parities for these sows varied from 0 to 6. The distribution of parity over both trial and treatment is shown in Table 1. Sows were group-housed throughout gestation. Ten days before their farrowing date, sows were placed in conventional farrowing crates (2.28 m long x 0.6 m wide x 1.0 m high) located in two adjacent rooms. Each crate had an adjoining creep area with a thermostatically controlled heat mat (Farm Duty® Model # M6C17FB9H) for the piglets comfort. Sows were weighed at crate entry, day 1 post farrowing, and day 17 post farrowing. Sows were weaned at 18 +/- 2 days. Backfat measurements were taken by ultrasound on day 1 and day 17 post farrowing (+/- 1 day), and on the day of post-weaning estrus. Sows not returning to estrus by day 10 post-weaning were weighed and backfat measurements taken on day 10, as well as on the day of subsequent return to estrus.

TABLE 1. Distribution of parity of sows weaned at 0800h (AM) and 1645h (PM) in Trial 1 and Trial 2.

	AM			PM		
Parity	Trial 1	Trial 2	Total	Trial 1	Trial 2	Total
0	4	1	5	4	1	5
1	1	5	6	1	5	6
2	4	2	6	4	2	6
3	6	4	10	5	4	9
4	2	5	7	2	4	6
5	3	2	5	3	1	4
6	2	1	3	2	4	6

Sow and Litter Management

Sows were monitored at regular intervals during farrowing. Sows experiencing a delay of more than 30 minutes between piglet deliveries were checked to ensure the birth canal was clear and then injected with 1 ml of oxytocin (20 I.U./ml Rhone Merieux, Victoriaville, PQ Canada), administered in the vulva. Sows two days past their farrowing date were induced with 1ml of Lutalyse (Pharmacia and Upjohn Animal Health, Orangeville, ON Canada) injected in the vulva on the afternoon of the second day. If farrowing had not commenced by the next morning, 1 ml of oxytocin was administered. All live born, stillborns, and mummified fetuses delivered were recorded for each sow.

Piglets were cross fostered within 48 hours of birth to ensure equal litter size for all sows. Piglets were processed uniformly within one day of birth. This procedure included ear notching for identification purposes, teeth clipping, and administration of 1 ml of Exenel® i.m. (Pharmacia and Upjohn Animal Health, Orangeville, ON Canada). On day three, tails were clipped and 2 ml of iron (Ironol 100 Rhone Merieux, Victoriaville, PQ Canada) and 1 ml of Exenel® were injected i.m. Castrations were done on day 7 at which time the piglets also received 1 ml of Exenel®. Preweaning piglet deaths in each litter were recorded with reason and date.

Piglets had free access to functional water nipples from birth and to creep feed from day 14 until weaning. Piglets were weighed and weaned into nursery pens at 18 days of age +/- 2 days (day of birth = day 1). At the time of weaning it took no longer than 10 minutes from the time the first sow was weaned until the time that the last sow was weaned. Sows remained in the farrowing crates, except for estrus detection, to facilitate ease of blood sampling and observation. All procedures and animal care followed those recommended by the Canadian Council on Animal Care (1993).

Light Program

Sows were maintained under 9 hours of light and 15 hours of dark from the time of crate entry throughout the experiment. All outside windows were covered and sealed with thick cardboard to ensure no outside light could filter in. Lights came on at 0800h and went off at 1700h. Any work done in the animal rooms during the dark period was

done using portable 40W soft red light which was extinguished immediately after work was completed. Heat lamps were not used.

Feeding Schedule

Sows were fed 3.5 kg of a 16% crude protein barley-based nurse-sow ration from the time they entered the farrowing crate until the day of farrowing. After farrowing, the sow ration was increased by 0.5 kg/day increments to ad lib intake. On the day of weaning , all sows to be weaned were fed their daily ration in two installments- one half in the morning and one half in the afternoon, immediately after weaning times. This was done to ensure that the metabolic and endocrine responses to feeding were identical for each treatment immediately after weaning. Post weaning, sows were fed a 14.5% crude protein barley-based dry sow ration at a rate of 3.5 kg/day. The commercially prepared rations were formulated to meet or exceed the NRC (1998) requirements for nursing sows or dry sows, respectively. Sows had free access to fresh water at all times via a water nipple. From the time each sow entered its crate until 3 days post-breeding, daily feed allotment and feed remaining were weighed and recorded.

Estrus Detection and Breeding

From the day following weaning until standing estrus sows were taken individually to a separate room for approximately 10 minutes of exposure (fenceline and direct) to mature boars and then returned to their crates. Initial breeding of sows was done using a mature boar and then followed with two artificial inseminations approximately 6-10 h and again at 24h after the initial breeding. All semen was fresh

from Cotswold Canada Ltd. (Winnipeg, MB, Canada). Semen was stored at 18 °C and was used within 42 hours of collection..

Weaning to estrus interval (WEI) was recorded for each sow. Sows were checked for estrus at 0800h, 1200h, 1600h, and 2000h for signs of heat/standing heat. Additionally, sows were continuously monitored throughout the day and night during blood sampling and signs of heat/standing heat were recorded. All estrus checks were done by four technicians familiar with signs of estrus and standing estrus. Signs of estrus included swelling of the vulva, redness of the vulva, mucus secretion, restlessness, and willingness to stand to back pressure. Standing estrus was defined as the time at which the sow stood to back pressure by a technician. Three days after first successful breeding, sows were removed from their crates and placed in groups of three similar sized sows. Sows were monitored for return to estrus and checked for pregnancy by ultrasound 30 to 40 days after breeding. Subsequent sow reproductive performance was determined by recording pregnancy and farrowing rates, number of piglets born alive, stillborns, mummies, and piglet weights at birth.

Catheterization

A total of 18 mixed parity sows were fitted with ear vein catheters on the day prior to weaning. Thirteen sows were catheterized in the June trial and five sows were catheterized in the November trial. Parity distribution over trial and treatment is shown in Table 2.

TABLE 2. Distribution of parity of blood sampled sows weaned at 0800h (AM) or 1645h (PM) in Trial 1 and Trial 2.

	AM			PM		
Parity	Trial 1	Trial 2	Total	Trial 1	Trial 2	Total
1	1	1	2	0	2	2
2	1	0	1	1	0	1
3	2	1	3	3	0	3
4	2	0	2	1	1	2
5	1	0	1	0	0	0
6	0	0	0	1	0	1

Sows were removed from their crates and restrained with a nose snare. The ear was first shaved, washed with a mixture of Hibitane (Wyeth-Ayerst Canada, Inc., Montreal, PQ, Canada) and water, swabbed with Betadine (Purdue Frederick Inc., Pickering, ON, Canada), and then wiped with isopropyl alcohol. An elastic was placed around the base of the ear to occlude the veins draining the ear and thereby add definition to the ear vein. The elastic was removed once the needle and catheter were in the vein. A one inch 14 gauge needle (Becton Dickinson Franklin Lakes NJ 0741-1884) was used to penetrate the vein and 75 - 90 cm of catheter tubing beveled at the insertion end (Dural Plastics and Engineering, Auburn, NSW,2128, Australia, O.D. 1.5mm x I.D 1.00mm

11100-2042) was threaded through the needle into the ear vein to a length measured to reach the jugular vein. A sterile normal saline solution was used to keep the catheter patent during insertion. Catheter patency was maintained with a 100 USP heparinized saline solution prepared using Sigma sodium heparin from porcine intestinal mucosa (Lot 117H0805 9041-08-1 Sigma Chemical Co. PO Box 14508 St. Louis, MO 63178). A 10000 USP stock solution was first prepared by adding 1.397 g of heparin to 25 ml of normal sterile saline. The exposed end of the tubing was plugged using a catheter adapter made from a one and a half inch 19 gauge needle with the tip ground off and a catheter adapter cap (Becton Dickinson, Sandy, UT, USA). The point of insertion into the ear was sealed with a few drops of Vet-Bond (No. 1469 3M Animal Care Products St.Paul, MN 55144-1000) to stop any excess bleeding and to seal the wound.

A butterfly bandage was fashioned out of a small strip of Kendall Curity tape (Standard Porous Tape #6613 Kendall Health Care Products Co., Mansfield, MA, USA) to anchor the catheter in place. Large pieces of Elastoplast tape (7.5 cm x 4 m Elastic Adhesive Tape #10300 Smith and Nephew, Lachine, Quebec) were glued using livestock cement (Ag-tek Cement Kane Enterprises Ag-tek division PO Box 1043 Sioux Falls, SD 5101) directly to the back of the ear, base of the ear, and the top of the sows' shoulder to prevent the catheter tubing from resting against the skin. The tubing was covered and secured to the Elastoplast using 1- and 2-inch Kendall Curity tape to protect it from rubbing or catching. Excess tubing was gathered into a small plastic bag open at one end to allow easy access to the adapter for sampling. A 10-inch piece of surgical netting (Surgilast-Size 4 Glenwood Laboratories Oakville, ON) was placed over the ear and

glued to the base of the ear for further protection of the catheter and intravenous insertion site.

To help reduce the risk of infection, each sow that was catheterized was given 10 ml i.m. of Penlong (Rogar STB Inc., London, ON, Canada) at the end of the catheterization procedure.

Blood Sampling

Blood samples were collected from the 18 catheterized sows starting the day of weaning (day 1). On days 1, 2, and 3, samples were collected every 30 minutes for two eight-hour windows as the mean number of detectable LH peaks does not differ significantly between samples taken at 30 minute intervals and 10 minute intervals (Diekman et al 1991). The first eight hour window was from 0830 h to 1630 h and the second from 1700 h to 0100h. Using the assumption that sows weaned at 18 days will usually show signs of estrus on day 4-5, a supplementary window from 0200h to 0800h was added to the regular sampling schedule beginning on day three. Samples were taken at 60 minute intervals during this window. (Supplementary sampling from 0200h to 0800h was started on day 2 for one sow that showed signs of estrus the morning of day 2). Sampling followed this schedule for two days after the sow was first successfully bred, at which time sampling was terminated.

Three ml of blood was withdrawn at half hour intervals (i.e. 0830h, 0930h etc.) and 5ml of blood was withdrawn on every hour (0900h, 1000h, etc). Serial blood samples were collected from the catheters by drawing out heparinized saline solution left in the catheter using a sterile 5-ml syringe, drawing the required amount of blood in a

second 5-ml sterile syringe, and then flushing the catheter with 1.5 ml of 10 USP heparinized saline solution in a sterile 3-ml syringe to prevent clotting between samples. Blood collected was placed into nonheparinized 16 x 100mm borosilicate tubes where it was covered with plastic film and stored in a cold water bath until transfer to 4°C cold storage at the end of the day. Blood samples were centrifuged the next morning at 2200rpm for 20 minutes. Serum was pipetted into 7-ml plastic scintillation vials and stored at -20° C until analysis for LH, estradiol, and progesterone.

Endocrine Analysis

Progesterone

Serum progesterone (P4) levels were analyzed using a commercial solid phase radioimmunoassay (RIA) kit (Coat-a-Count, Diagnostics Products Corporation, Los Angeles, USA Lot # 795). The range of the standard curve was 0.1ng/ml to 10 ng/ml of P4. I^{125} was used as the tracer with approximately 51000 cpm and maximum binding of 40%. Non-specific binding of the assay was ≤ 2.56 %. All materials were allowed to come to room temperature before use in the assay. For all standards and samples, 100 µl of serum was pipetted into polypropylene tubes precoated with rabbit antibodies to P4. I^{125} tracer was added to all tubes within a 10 minute time period. Tubes were then incubated for 3 hours at room temperature. The antibody bound portion was separated by decanting the supernatant and remaining radioactivity was read in a gamma counter (LKB

Wallac 1282 Compu Gamma Universal Gamma Counter). Intra-assay and inter-assay coefficients of variation over 5 assays were ≤ 9.84% and ≤ 11.43%.

Estradiol

Estradiol 17-β (E_2) was analyzed using a double antibody radioimmunoassay (Ultra Sensitive Estradiol RIA Diagnostic Systems Laboratories - 4800, Los Angeles, USA Lot # 01280). All materials were allowed to reach room temperature before the assay was started. The standard working curve values were 2.5 pg/ml - 250 pg/ml. I^{125} was used as the tracer with total counts of approximately 64000 cpm and maximum binding of 50%. Non-specific binding of the assay was ≤ 2.1 %. 200 ul of serum from all standards, controls and samples was pipetted into 12mm x 75mm test tubes. 100 µl of rabbit anti-estradiol (polyclonal) serum in a protein based (BSA) buffer was added to all tubes except total count tubes and NSB tubes. All tubes were vortexed and incubated for one hour at room temperature. 100 ul of estradiol I-125 reagent was added to all tubes. Tubes were vortexed and incubated for three hours at room temperature for 2 hours. One ml of precipitating reagent containing goat anti-rabbit gamma globulin serum was added to all tubes except total count. Tubes were vortexed and allowed to incubate at room temperature for 15 min. All tubes were centrifuged at 3000 rpm for 20 min. Supernatant was decanted and radioactivity remaining in the pellet was read in a gamma counter (LKB Wallac 1282 Compu Gamma Universal Gamma Counter). Intra-assay and inter-assay coefficients of variation over 6 assays were ≤ 16.6% and ≤ 13.6% respectively.

Luteinizing Hormone

LH was analyzed in the Department of Veterinary Physiological Sciences at the Western College of Veterinary Medicine at the University of Saskatchewan. The assay used was a heterologous double antibody RIA as described by Kingsbury and Rawlings (1993) and Currie and Rawlings (1989). Standards were lyophilized porcine LH (USDA - pLH-B1) with a working standard curve from 0.0625 to 8 ng/ml. Assay standards were diluted in 5% BSA (5 g bovine serum albumin Sigma A4503 per 100 ml PBS with gel). The primary antibody used was raised in rabbits against bovine LH, with an initial working dilution of 1:40000 prepared in a 0.2% NRS (normal rabbit serum). The second antibody was raised in sheep against rabbit-γ-globulins and was diluted in PBS with gel (without NRS). The tracer used was iodinated bovine LH and was diluted in PBS with gel to provide 13000 - 18000 cpm per 200 µl. 200 µl of standards and samples and 200 µl of primary antibody solution were added to all tubes except total count and NSB tubes. 200 µl of 0.2% NRS was added to the NSB tubes in place of the first antibody. All tubes were vortexed and incubated in a cold room overnight. The following day, 200 µl of tracer was added to all tubes, vortexed and incubated in a cold room overnight. The next day, 0.5 ml of the second antibody solution and 0.5% PEG (polyethylene glycol) was added to all tubes except the total counts. Tubes were vortexed and incubated in a cold room overnight. On the final day, all tubes except total counts were centrifuged for 10 - 15 minutes at 3000 rpm and decanted. The amount of I^{125} label in pellets was read for one minute on a gamma counter. All unknowns and pools were analyzed in 4 assays and the inter-assay and intra-assay coefficients were ≤21.1% and ≤8.7% respectively. Non

specific binding was ≤5% and the sensitivity (defined as the lowest standard concentration different than zero) was 0.03 ng/ml.

Statistical Analysis

Breeding and Farrowing Performance

In each trial, sows were assigned to weaning treatment (AM (n=42) or PM (n=42) weaning) using a stratified random sampling procedure with respect to parity. The model used for analysis of breeding and farrowing performance for both trials included the effects of weaning treatment, parity, and the interaction of weaning treatment and parity as well as trial effects and interactions of trial with weaning treatment and parity. Trial and interactions with trial were considered to be random effects while weaning treatment, parity, and their interactions were considered fixed effects. The error term used for this analysis was treatment by trial by parity. Comparisons for hours/days from weaning to standing estrus, subsequent born alive, still born, and mummies were done using the General Linear Model functions of the Statistical Analysis System (SAS version 6.11, 1986). Variances in weaning to estrus intervals were compared using a test of homogeneity of variance (F-statistic). WEI results by treatment were further analyzed using a t-test allowing for unequal variances. Results of the t-test are reported in Appendix Table A7.

Hormones

To test for the effect of treatment over time at each event window (i.e. day of weaning, day after weaning, day before standing estrus, day of standing estrus, and day after standing estrus), endocrine data was analyzed as a split plot. The model used for repeated measures was; treatment (AM (0800h) or PM (1645h) weaning time), sow within treatment, event, event-by-treatment interaction, and event-by-sow within treatment. Linear contrasts were used to determine how each treatment group differed in endocrine concentrations at each of the 5 event windows. In a preliminary analysis, parity and trial effects were calculated using the model: trial, treatment, parity group (parity 1-2 = 'early parity group', parity 3-6 = 'late parity group'), treatment-by-trial interaction, treatment-by-trial-by-parity group interaction, sow within treatment-by-trial-by-parity group, event, event-by-treatment interaction, event-by-parity group interaction, event-by-trial interaction, and event-by-sow within treatment-by-trial-by-parity group interaction. However, linear contrasts were non-estimable using this model. Due to lack of any significant effects of parity or trial or interactions of these variables for progesterone, LH, and only a significant difference for *overall* mean concentrations of estradiol between parity groups (early parity group= 3.90± 0.77, late parity group = 6.46 ± 0.65, P=.0373), this model was not used.

The beginning of the LH and estradiol surges were defined as that time in which the concentration increased at least 35% over the average of the previous 4 hours. As described by Niswender, Reichert and Zimmerman (1970) an increase in LH must be maintained for a minimum of eight hours to be considered a surge. Maximum peak

values of the LH and estradiol surges were the highest observable value during the surge. Baseline concentrations and pulsatility of LH was calculated as described by Evans et al (1994). To determine baseline concentration of LH, mean concentration for each sow was determined and any peak equal to or greater than 3 standard deviations above the mean was removed. Calculations were repeated until all points were less than 3 standard deviations from the mean. A pulse was determined as a point greater than 3 standard deviations from the baseline value that was followed by no more than one other peak value. Baseline concentrations and pulsatility were compared across treatments using the General Linear Model functions of the Statistical Analysis System (SAS 6.11, 1986).

Comparisons of the occurrence of LH and estradiol surges and LH pulsatility during either the light or dark phases were done using an R x C contingency table in a chi-squared test.

CHAPTER 4

RESULTS

Reproductive Performance

Rebreeding Performance

There were no significant differences between those sows weaned at 0800h (AM; n=42) and 1645h (PM; n=42) in the number of days or hours from weaning to first signs of estrus or first standing estrus (standing estrus is defined for the purposes of this trial as the time at which the sow stood to back pressure) (Table 3). Overall rebreeding performance is shown in Table 4. Weight change from day of farrowing to day of weaning, average daily feed intake during lactation, age of piglets at weaning, number of piglets weaned, and weaning weight of the litter were examined as possible variables influencing the WEI. No significant differences were found between treatments for these variables (Table 5), nor did they have a significant effect on hours/days to standing estrus. There were no significant effects of parity on WEI, ADFI, number of piglets weaned or weaning weight of litter, although 6th parity sows tended to wean fewer piglets (P=0.0732). There were no significant differences between trials in breeding performance. All values reported in the results are least squares means ± standard error of the means, unless otherwise stated.

TABLE 3. Effect of hour of weaning (AM = 0800h;PM = 1645h) on WEI.

Parameter	Treatment*		
	AM	PM	P
Hours from weaning to first signs of estrus	92.60± 13.94	90.00± 13.94	0.8951
Hours from weaning to standing estrus	99.59± 5.52	106.63± 5.52	0.3705
Days from weaning to standing estrus	4.15 ±0.23	4.44± 0.23	0.3705

*values are least squares means±standard error of the means

TABLE 4. Rebreeding performance of sows weaned at 0800h (AM) and sows weaned at 1645h (PM). Photoperiod was from 0800h to 1700h.

Parameter	Treatment	
	AM	PM
WEI range (hours)	25.00 - 169.00	17.25 - 232.25
Number of sows not showing estrus by the end of day 10	0	2
Pregnancy rate	92% (39/42)	97.5% (39/40)
Farrowing rate	83% (35/42)	87.5% (35/40)

TABLE 5. Comparison of pre-weaning performance of sows weaned at 0800h (AM) and sows weaned at 1645h (PM).

Parameter	Treatment*		
	AM	PM	P
Lactation length (d)	17.40± 0.20	17.59± 0.20	0.5064
Weight change during lactation (kg)	-10.54± 2.24	-6.38± 2.08	0.1794
ADFI during lactation (kg)	5.66± 0.12	5.79± 0.12	0.4824
Number of piglets weaned per litter	9.54± 0.26	9.11± 0.26	0.2609
Total weaning weight of litter (kg)	57.11± 1.75	55.95± 1.75	0.6400

*values are least squares means±standard error of the means

However, synchrony of standing estrus was significantly different ($P<.01$). Sows weaned in the afternoon had a significantly higher variation in the hours from weaning to estrus (mean = 106.63h, s^2= 42.25 h) than sows weaned in the morning (mean = 99.59h, s^2 = 27.89 h).

There were no trial effects observed in the WEI. Overall rebreeding performance for each trial is shown in Table 6.

TABLE 6. Rebreeding performance of sows weaned during Trial 1 and sows weaned during Trial 2. Photoperiod was from 0800h to 1700h.

Parameter	Treatment	
	Trial 1	Trial 2
WEI range (hours)	17.25 - 232.25	25.00 - 145.00
Number of sows not showing estrus by the end of day 10	2	0
Pregnancy rate	97% (40/41)	92% (38/41)
Farrowing rate	85% (35/41)	85% (35/41)

Sows in trial 1 had a significantly greater ADFI (6.20 ± 0.09 kg) than those in trial 2 (5.22 ± 0.10) (P=.0001). Further, sows in trial 1 weaned significantly larger litters (9.72 ± 0.25 piglets per litter) than sows in trial 2 (8.92 ± 0.26 piglets per litter) (P=.0355). Litter weaning weights in trial 1 (58.86 ± 1.69 kg) also tended to be larger than in trial 2 (54.09± 1.73 kg) (P=.0526). Lactation length, and weight change during lactation were not different between the two trials.

Average daily temperatures in the barn during both trials were not different. Average temperature throughout trial 1 and trial 2 were maintained at 24.27 °C and 24.76 °C respectively. However, as seen in the temperature profile in Figure 2, higher maximum temperatures were achieved in part of trial 1.

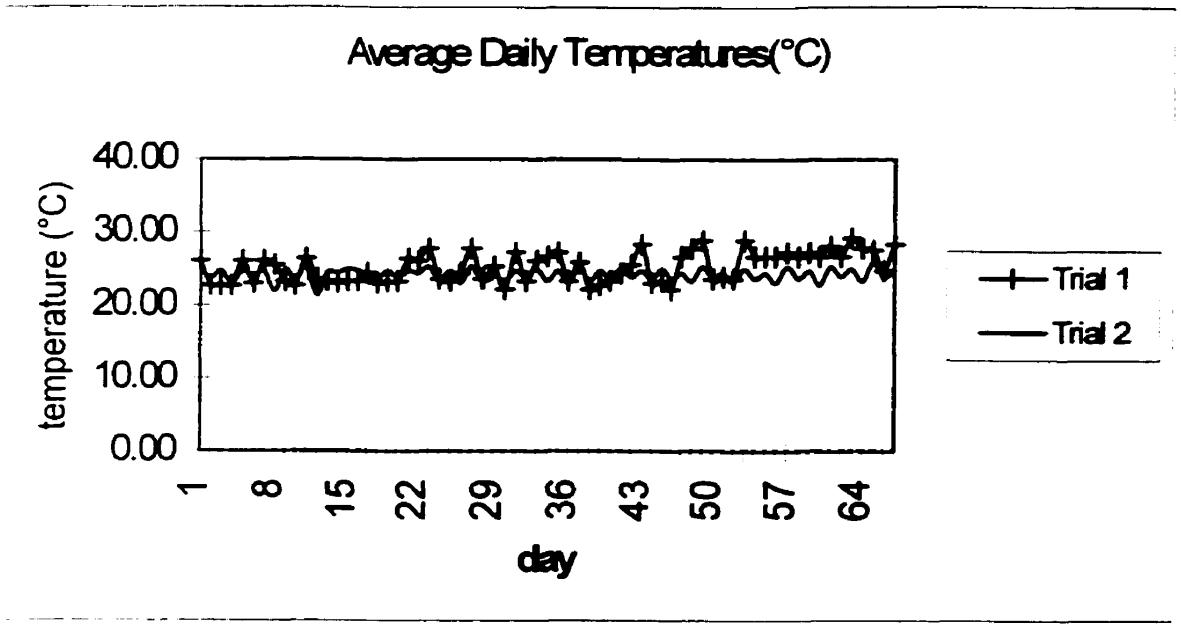

Figure 2. Average daily temperatures (°C) for Trial 1 and Trial 2

Farrowing Performance

The farrowing rate was 85% for each trial. There was no evidence of abortion in any of those sows that remained open. There were no significant differences between treatments for number of piglets born alive, number stillborn, number of mummies, or litter birth weights. Results of the subsequent farrowing are listed below in Table 7.

TABLE 7. Subsequent farrowing performance of sows weaned at 0800h (AM) and sows weaned at 1645h (PM). All sows were mated naturally and by AI at the first estrus post-weaning.

Parameter	Treatment*		
	AM	PM	P
Number born alive	10.65± 0.49	10.28± 0.49	0.5980
Number stillborn	1.08± 0.22	1.28± 0.22	0.5341
Number mummies	0.45± 0.13	0.40 ±0.13	0.7594
Litter birth weight (kg)	17.64 ±0.66	16.24 ±0.66	0.1427

*values are least squares means±standard error of the means

There were no significant effects of trial on born alive, stillborn, mummies or litter birth weights. Parity had an effect on number stillborn per litter (P=0.0147), however multiple means comparison tests were unable to detect the difference. The difference most likely resulted from parity 0 and parity 1 sows having 0.44± 0.41 and 0.54± 0.37 stillborns respectively, in contrast with parities 4 and 6, having 2.18± 0.37 and 2.16± 0.50 stillborns, respectively. No other parity effects were found.

Endocrine Analysis

Sampled sows

Performance of all sows used for endocrine analysis were analyzed to insure that they followed a pattern consistent with that of the entire data set. Sampled sows were consistent with the overall group as demonstrated in Table 8. All sows used for sampling had a detectable LH and estradiol surge with the exception of one sow in the AM

treatment and one sow in the PM treatment in which the catheter was lost before the sow was bred. Both of these sows were successfully bred and subsequently farrowed. Additionally, sow 459G in trial 2 (AM treatment) showed estrus and was bred on the day after weaning without showing any detectable estradiol or LH surge. She subsequently farrowed a litter of 10 born alive and 1 stillborn. Farrowing rates for both treatments were 88% (8/9). Sow 27G (Trial 1, AM treatment) and sow 40G (Trial 1, PM treatment) appeared to have normal endocrine profiles, were successfully inseminated, pregnancy checked positive at day 30 of gestation, but were subsequently open and did not farrow.

Mean serum hormone concentrations for each day are pooled samples. Mean serum hormone concentrations for day of weaning are those samples taken only after weaning.

TABLE 8. WEI and subsequent farrowing performance of venous blood-sampled sows weaned at 0800h (AM) and 1645h (PM)..

Parameter	Treatment*		
	AM (n=9)	PM (n=9)	P
WEI (hours)	89.66 ± 12.17	114.91 ± 12.17	0.1619
Number born alive	10.75 ± 1.01	11.00 ± 1.01	0.8643
Number stillborn	1.62 ± 0.39	1.25 ± 0.39	0.5118
Number mummies	0.25 ± 0.31	0.62 ± 0.31	0.4193
Litter birth weight (kg)	16.81 ± 1.32	16.32 ± 1.32	0.7981

*values are least squares means±standard error of the means

Progesterone

There were no significant differences over time in mean serum progesterone concentrations between sows weaned at 0800h (n=9) and sows weaned at 1645h (n=9). The progesterone profile over time is shown in Figure 3. There were no other significant effects or interactions. See Appendix Table A1 for table of mean serum concentrations of progesterone in AM and PM weaned sows.

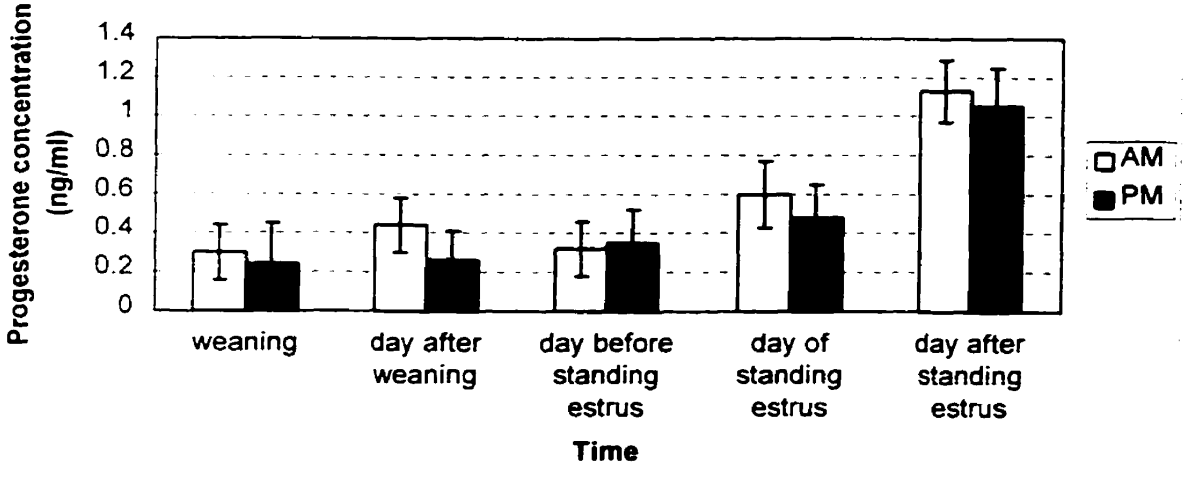

Figure 3. Serum concentrations (lsmeans ±sem) of progesterone in sows weaned at 0800h (AM) and 1645h (PM)

Estradiol

There were no significant differences over time in mean serum concentrations of estradiol between AM weaned sows and PM weaned sows. Estradiol profiles for the two treatment groups over time are shown in Figure 4. No other significant effects or

interactions were found. See Appendix Table A2 for mean serum concentration of estradiol in AM and PM weaned sows.

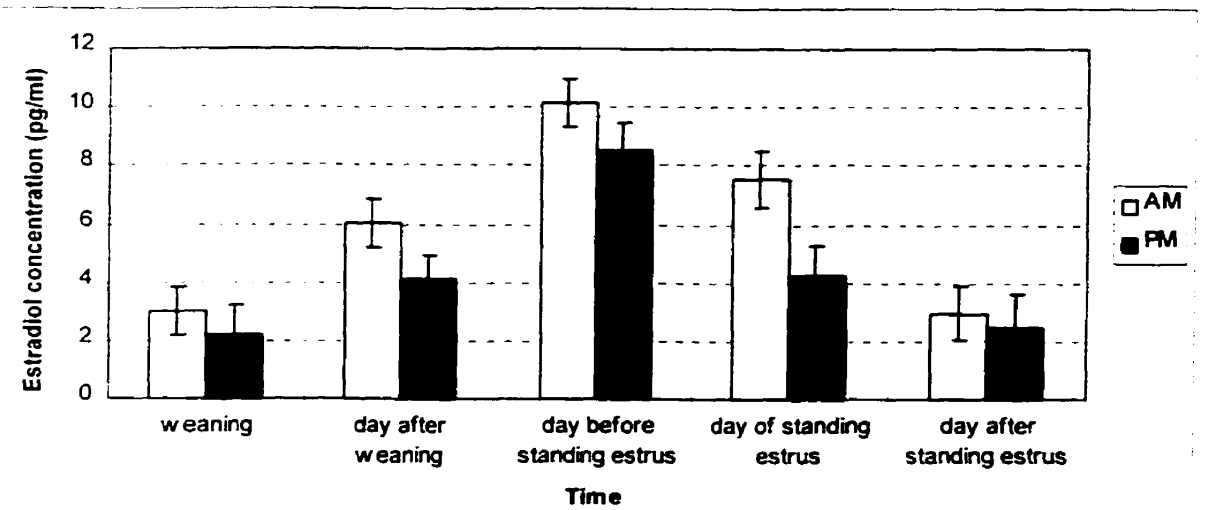

Figure 4. Serum concentrations (lsmeans ±sem) of estradiol in sows weaned at 0800h (AM) and 1645h (PM)

In those sows having a detectable estradiol surge, estradiol surge durations and surge maximum values were not significantly different between treatments. Values are shown in Table 9. There were no differences between trial or parity on estradiol surge duration or maximum values, however the postweaning estradiol surge began sooner (P= 0.0592) after weaning in trial 1 sows (19.18± 5.19 h) than in trial 2 sows (40.00± 8.62 h). Further, the average duration from weaning to the beginning of the estradiol surge was

16.70± 4.96 h in late parity sows (parities 3-6) and 40.80± 7.01 h in early parity sows (parities 1-2) (P= 0.0149).

TABLE 9. Estradiol activity in AM (n=7) and PM (n=8) weaned sows having a detectable estradiol surge

Parameter	Treatment*		
	AM	PM	P
Estradiol surge duration (hours)	99.28± 13.16	74.28± 13.16	0.2043
Estradiol surge maximum peak concentration (pg/ml)	16.9± 1.40	13.6± 1.40	0.1159
Hours from weaning to beginning of estradiol surge	18.85± 7.17	29.87± 6.71	0.2823
Hours from weaning to peak of estradiol surge	86.85± 6.00	87.00± 5.61	0.9864
Interval from onset of surge to peak value of surge (hours)	68.00± 8.73	57.12± 8.16	0.3796

*values are least squares means±standard error of the means

The time during the day at which the postweaning estradiol surge began was significantly different between treatments. Sows weaned in the AM had a greater proportion of estradiol surges beginning during the scotoperiod than PM weaned sows (χ^2 = 9.78, P< 0.025) (Table 10). The time during the day that the estradiol surge reached it's peak value was not different between treatments (Table 11).

TABLE 10. Period during which the postweaning estradiol surge began in AM (n=7) and PM (n=8) weaned sows having a detectable estradiol surge

Time	Number of Sows	
	AM	PM
0800h - 1200h (light)	0	4
1200h - 1700h (light)	1	0
1700h - 2400h (dark)	2	4
2400h - 0800h (dark)	4	0

TABLE 11. Period during which the peak value of the postweaning estradiol surge occurred in AM (n=7) and PM (n=8) weaned sows having a detectable estradiol surge

Time	Number of Sows	
	AM	PM
0800h - 1200h (light)	3	2
1200h - 1700h (light)	1	2
1700h - 2400h (dark)	0	0
2400h - 0800h (dark)	3	4

Luteinizing Hormone

Baseline concentrations of LH, surge durations, maximum peak values of the surge, and hours from weaning to surge activity are shown in Table 12. The number of pulses per sampling period (sampling period = 24 hours) are also shown. There were no differences between treatments for any of these parameters. There were no effects of parity group, trial, or interactions, although sows in trial 1 tended to have a higher

baseline LH concentration (1.50± 0.26 ng/ml) than those sows in trial 2 (0.63± 0.39 ng/ml) (P= 0.0940). No differences were found in WEI between those sows having high baseline concentrations (>1.0 ng/ml) and those sows having low LH baseline concentrations (< 1.0 ng/ml).

Treatment did not affect the interval between the estradiol peak and the LH peak. However, PM weaned sows tended to have a higher variation (P<.10) (s = 6.10) than AM weaned sows (s = 3.22) in the time from the estradiol peak value to the time of the LH peak value. There was no significant difference between treatments in the variation of the time from weaning to the time of the LH peak. Further, early parity sows had a shorter interval between the estradiol peak and the LH peak than late parity sows (early parity : 11.30± 1.59h. late parity: 18.20± 1.12h) (P=0.0037). There were no trial effects on the interval between the estradiol peak and the LH peak.

TABLE 12. LH activity in sows weaned at 0800h (AM) and sows weaned at 1645h (PM).

Parameter	Treatment*		
	AM	PM	P
Baseline concentration (ng/ml)	1.28 ± .33	0.84 ± 0.34	0.3519
LH surge duration (hours)	21.25 ± 5.56	23.32± 3.69	0.7613
Maximum peak value of surge (ng/ml)	3.99± 1.75	3.87 ± 1.11	0.9534
Pulses (per sampling period)	0.50± 0.16	0.53± 0.14	0.8691
Hours from weaning to beginning of LH surge	92.07± 9.66	87.31± 9.04	0.7250
Hours from weaning to peak value of LH surge	103.00± 7.23	99.56± 6.76	0.7342
Interval from beginning of surge to peak value (hours)	10.92± 3.32	12.25± 3.10	0.7761
Interval from estradiol peak to LH peak (hours)	16.14± 1.88	15.68± 1.76	0.8627

*values are least squares means±standard error of the means

The occurrence of peak values of the LH surge during the scotoperiod tended to be higher in those sows weaned at 0800h than in those sows weaned at 1645h ($\chi^2 = 3.605$, $P<.10$). Of the seven AM weaned sows having a detectable LH surge, six sows reached their peak during the dark phase and one sow reached her maximum LH surge value during the light phase. In the eight PM weaned sows having a detectable LH surge, five sows reached peak values during the light phase and three sows reached peak values in the dark phase. Occurrence of maximum peak values of the LH surge along with the

occurrence of first signs of estrus during the light or dark phase (further broken into quadrants) are shown in Table 13. Hormone profiles for each treatment relative to light cycles are shown in Figure 5.

TABLE 13. Occurrence of first signs of estrus and peak values of LH surge in sows weaned at 0800h (AM) and sows weaned at 1645h (PM).

Time	Number of Sows			
	AM		PM	
	signs of estrus	LH surge peak	signs of estrus	LH surge peak
0800h - 1200h (light)	4	0	7	3[d]
1200h - 1700h (light)	1	1[a]	1	2[e]
1700h - 2400h (dark)	1	4[b]	0	1[f]
2400h - 0800h (dark)	1	2[c]	0	2[g]

[a] LH peak values occurring at 1530h
[b] LH peak values occurring at 1900h, 1900h, 2200h, 2330h
[c] LH peak values occurring at 0300h, 0500h
[d] LH peak values occurring at 0830h, 1030h, 1130h
[e] LH peak values occurring at 1230h, 1330h
[f] LH peak values occurring at 2030h
[g] LH peak values occurring at 0100h, 0300h

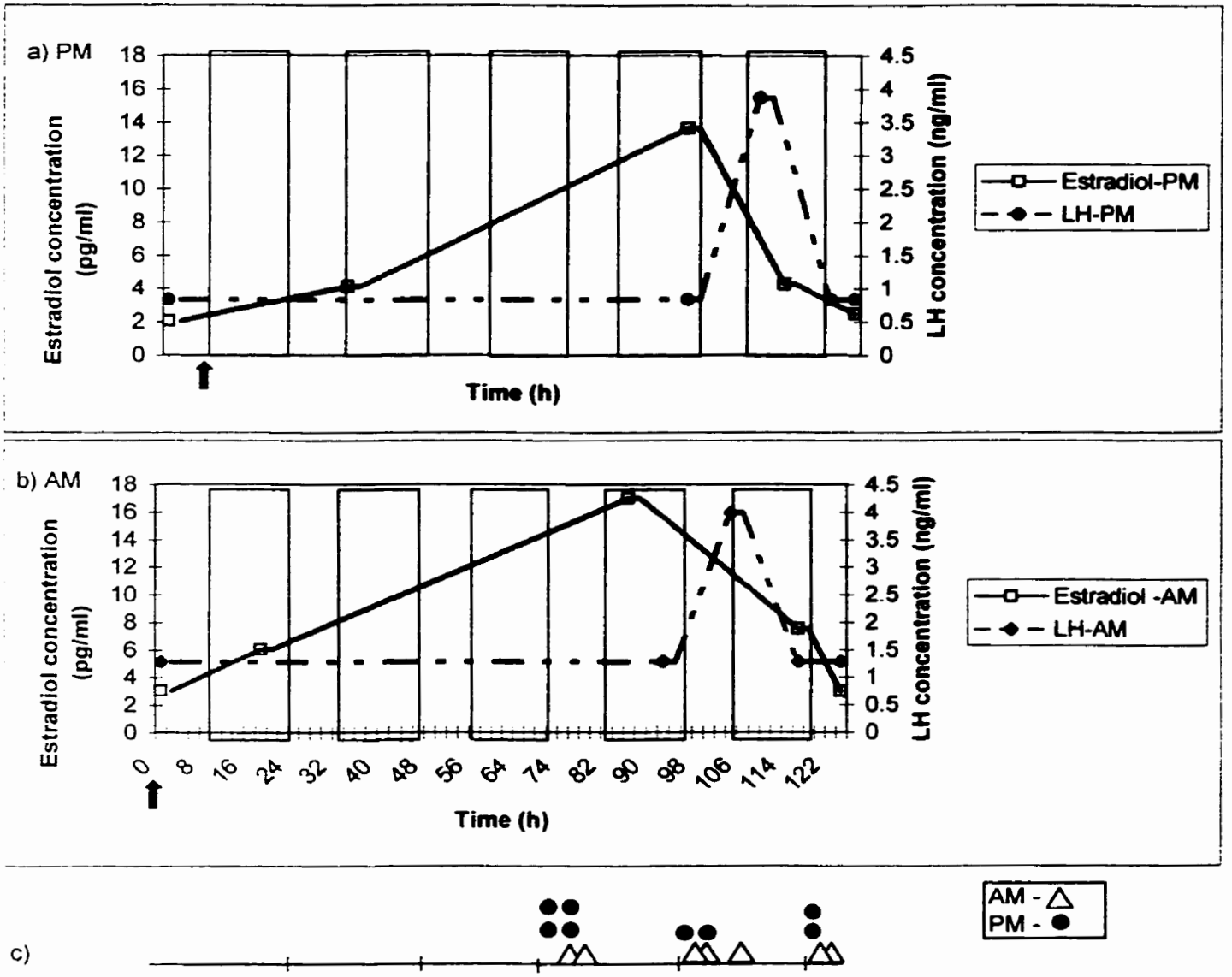

Figure 5. Hormone profiles* for a)PM (n=8) and b)AM (n=7) weaned sows having a detectable estradiol and LH surge.
c) Time of standing estrus for those sows having a detectable estradiol and LH surge AM (n=7) and PM (n=8)

Average WEI for all AM weaned sows(n=42) was 99.59h +/- 5.52 and average WEI for all PM weaned sows (n=42) was 106.63h +/- 5.52.
*values are lsmeans

light ⬆ indicates time of weaning.

dark

There were no differences between treatments for the frequency of distribution for the LH pulses between treatments, shown in Table 14. In both the AM and PM weaned sows, the majority of all pulses occurred during the light hours. Further dividing the light and dark phases into 4 quadrants demonstrated that very few pulses occurred in the time period of 2400h to 0700h for both treatments.

TABLE 14. Occurrence of LH pulses in AM and PM weaned sows throughout the sampling period.

Time	Number of Sows		Total (all sows)
	AM	PM	
0800h - 1200h (light)	20% (4/20)	32.4% (11/34)	28% (15/54)
1200h - 1700h (light)	45% (9/20)	29.4% (10/34)	35% (19/54)
1700h - 2400h (dark)	25% (5/20)	35.3% (12/34)	31% (17/54)
2400h - 0800h (dark)	10% (2/20)	2.9% (1/34)	6% (3/54)

LH concentrations did not differ significantly over time between the two treatments. The LH profile over time is shown in Figure 6. See Appendix Table A3 for mean serum concentrations of LH in AM and PM weaned sows.

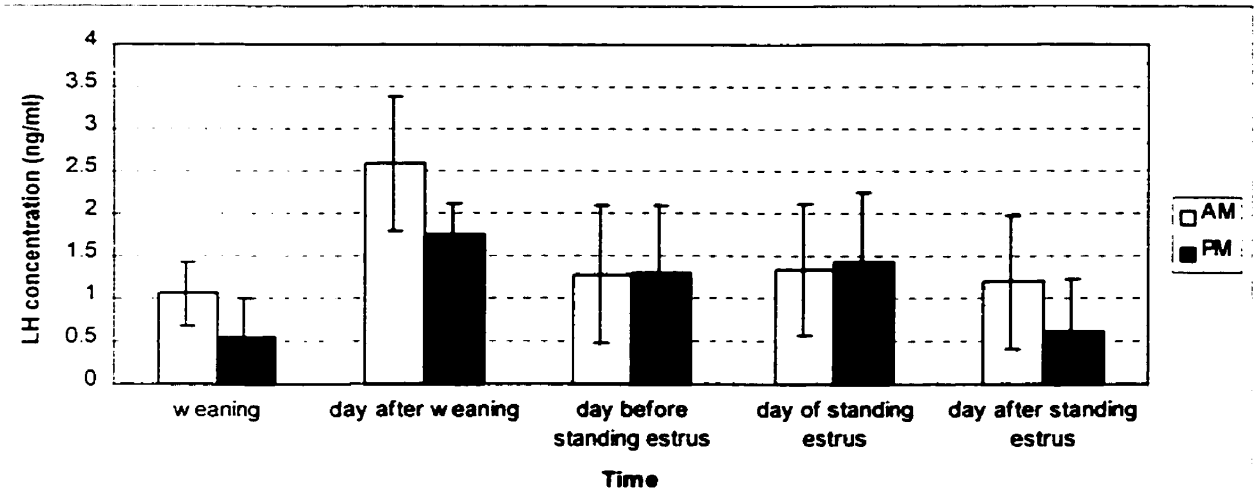

Figure 6. Serum concentrations (lsmeans± sem) of luteinizing hormone in sows weaned at 0800h (AM) and 1645h (PM)

Correlations

A positive correlation (P = .0001) was consistently seen between born alive and litter birth weight in all correlation analysis done. There were no significant correlations between hours/days from weaning to standing estrus and subsequent farrowing performance (born alive, stillborn, mummies, litter weight) by treatment, or by overall group. Significant endocrine correlations and trends for sampled sows are shown below in Tables 15, 16, and 17, and for all sows in Table 18. (Correlation = P<.05, Trend = P<.10)

TABLE 15. Significant correlations and trends for sampled sows weaned at 0800h (AM; n=7).

Correlation**	r	P
LH surge peak value and LH baseline concentration	0.87759	0.0094
LH baseline concentration and WEI	0.72668	0.0266
E2 surge duration and WEI	0.86017	0.0130
Hours from weaning to LH peak and WEI	0.89209	0.0069
Hours from weaning to E2 peak and WEI	0.95454	0.0008
Trend*	r	P
E2 surge duration and LH baseline concentration	0.74146	0.0565

** significant at P<.05
* significant at P<.10

TABLE 16. Significant correlations and trends for sampled sows weaned at 1645h (PM; n=8).

Correlation**	r	P
E2 surge duration and LH baseline concentration	0.86536	0.0119
LH surge peak value and LH baseline concentration	0.92794	0.0026
Hours from weaning to LH peak and WEI	0.77965	0.0225
Hours from weaning to E2 peak and WEI	0.84355	0.0085
Trend*	r	P
LH baseline concentration and WEI	0.63239	0.0676

** significant at P<.05
* significant at P<.10

TABLE 17. Significant correlations for all sampled sows weaned at 0800h (AM; n=7) and 1645h (PM; n=8) (treatments combined).

Correlation**	r	P
LH surge duration and LH surge maximum value	0.79427	0.0007
LH baseline concentration and E2 surge duration	0.71327	0.0042
E2 surge duration and WEI	0.62375	0.0171
Hours from weaning to LH peak and WEI	0.76904	0.0008
Hours from weaning to E2 peak and WEI	0.88918	0.0001

** significant at P<.05

TABLE 18. Significant correlations for all sows (n=84) weaned at 0800h (AM) and 1645h (PM).

Correlation**	r	P
ADFI and total weaning weight of litter	0.36761	0.0006
ADFI and number of piglets weaned	0.25601	0.0195
Hours from weaning to first signs of estrus and WEI	0.76231	0.0002

** significant at P<.05

CHAPTER 5

DISCUSSION

Manipulation of the sow's reproductive cycle to increase performance in both the breeding and farrowing barns remains an area with many possibilities. While effects of altering lactation length have been well documented, the influence of light patterns relative to the actual time of weaning and the endocrinological and physiological response of the sow remain unclear. In this study, two groups of sows were weaned at two different times relative to lights on and lights off to investigate and better define the role that light cycle has on endocrine response and subsequent rebreeding and farrowing performance.

Farrowing rates and farrowing performance (stillborn, born alive, mummified) throughout this study were consistent with previous herd records and data recorded elsewhere in industry and research (Claus and Weiler 1985, Smith et al 1991, Prunier et al 1994, Peltoneimi et al 1999). Farrowing performance between treatments did not differ. There was a parity effect on the number stillborn, undetectable by multiple comparisons, but most likely the result of parities 0 and 1 having fewer stillborns than parities 4 and 6. An increase in the number stillborn with increasing parity has been attributed, in part to uterine fatigue as a result of an increase in collagen as well as to an accumulation of implantation scars on the uterus as it ages (as reviewed by vom Saal et al 1994). These can interfere with vascularization which may decrease the flow of nutrients

and hormones necessary for successful pregnancy and parturition (as reviewed by vom Saal et al 1994).

There was no significant difference in the average WEI between AM and PM-weaned sows. Similarly, there were no differences between treatments in the time from weaning to the time at which the sows began to display the first signs of heat. Thus, it can be estimated that those sows that were weaned in the afternoon will simply be approximately 8 hours behind those sows weaned in the morning. Using the mean WEI , it can be estimated that AM-weaned sows would return to estrus at approximately 1130h on the 5th day after weaning (day of weaning = day 1), while PM-weaned sows would return to estrus at 0300h, approximately 15 hours after the AM-weaned sows, accounting for the 8 hour lag interval and the slightly longer mean WEI. It is a definite advantage from a managerial standpoint to have the majority of sows begin to display estrus during the daylight hours, when barn staff are available and breeding will take place. Further, afternoon weaned sows did not wean heavier litters as a result of the 'extra' day allowed with the litter, and it therefore appears that there is little, if any advantage in weaning sows in the afternoon.

However, it is the variation in return to estrus which is of note. Sows weaned in the morning returned to estrus in a more synchronized group than those sows weaned in the afternoon. Given that s = 5.28 for the AM-weaned sows, and the majority of these sows first displayed estrus at approximately 1130h, these sows displayed standing estrus during daylight hours (0800h - 1700h) and would have a better chance of early detection by breeding staff. Those sows weaned in the afternoon having a greater variance may or may not begin to show signs of heat during the daylight hours when estrus would be

detected, given that the range of the WEI for PM-weaned sows was anywhere from 17.25h - 232.25h (a 215h range). This supports the data presented by Evans et al 1996 who noted that sows under a long day photoperiod weaned at 0400h (2h before lights-on) had a WEI between 92 - 110 hours (within an 18h range) while those sows weaned at 1600h (2 hours prior to lights-out) had a WEI between 80 - 134 hours (within a 54h range). Thus, it appears that while weaning immediately after lights-on did not alter the mean WEI, it did play a role in the synchrony with which those sows returned to estrus. With reference to the mean WEI of the PM-weaned sows, it is possible that the greater variation in the return to estrus of the PM- weaned group was a result of a number of these sows displaying first standing estrus during the dark period. Some of these PM-weaned sows may not have been detected at their true WEI as a result of this. However, the synchrony in the endocrine profile characteristic of the AM-weaned sows and absent in the PM-weaned sows suggests that the PM-weaned sows did have a greater variation in return to estrus, as the endocrine profile and WEI are closely linked.

A group of sows returning to heat in a synchronized fashion is desirable in that it makes estrus detection easier and increases the feasibility of a fixed insemination time. Further, those sows may remain in a uniform farrowing group, avoiding overly large or small farrowing groups and thus maximizing the efficiency of farrowing/breeding space in the barn.

There were no significant trial effects on WEI. Throughout gestation, sows were housed in a gestation barn exposed to natural and artificial light. In the gestation barn, sows used in the June trial were exposed to increasing photoperiod length, while sows used in the November trial were exposed to decreasing photoperiod. Four weeks prior to

the sow's predicted weaning date, these sows were housed in a short-day light controlled environment, as a four week period is thought to be sufficient to synchronize circadian rhythms within an organism (Paterson and Pearce 1990). Moving the sows into a light controlled environment four weeks prior to their predicted weaning date appeared to be able to correct for any seasonal effects on WEI, such as those reported by Xue et al (1994), who observed longer WEI in those sows weaned in June than those weaned in November. The current data suggests that this seasonal increase in WEI during the summer months can be avoided by exposing sows to a short day photoperiod 4 weeks prior to weaning.

In contrast to the increase in 'autumn abortions' observed in those sows bred in June reported by Claus and Weiler (1985) and Smith et al (1991), no evidence of abortion at any time was evident in the herd used in the current study. Further, the reduction in litter size at birth in subsequent farrowing as a result of summer breeding (as reported by Xue et al 1994) was not evident in this experiment. Previous herd records give no indication of a marked seasonal effect on subsequent farrowing performance or farrowing rates with this group of sows, which may be a reflection of careful management. Pregnancy rates were similar for both trial one and two at 97% and 92% respectively. Farrowing rates for both trials were identical at 85%. Season did not appear to have an influence on pregnancy or farrowing rates during this experiment.

Similarly, there did not appear to be a seasonal decrease in ovarian activity during the summer as suggested by Claus and Weiler (1985) and Smith et al (1991), as the post-weaning E_2 surge tended to begin earlier in sows in the June trial. The shorter time from weaning to the beginning of the E_2 surge in the summer sows suggests that the ovarian

activity in this study was not sufficiently diminished to produce characteristic seasonal endocrine effects, and in fact may suggest an increased activity. This increased activity may be expected to translate into an increase in surge value. However, maximum estradiol peak values or surge duration were not different between trials. Thus, while it seems clear that ovarian activity was not diminished in these sows, the extent to which it may be increased was limited.

Overall mean baseline LH concentrations tended to be higher in sows in the June trial. This is consistent with findings by Peltoneimi et al (1997a) who saw higher baseline concentrations in summer/early fall when compared with concentrations in winter/spring. It is in contrast to findings by Smith and colleagues (1991) and Kermabon et al (1995) who reported lower summer LH baseline concentrations and higher fall/winter concentrations. There does not appear to be a well defined seasonal pattern of LH baseline concentrations as the literature is contradictory. It is possible that the differences in LH concentrations are not exclusively seasonal effects, but could be the result of a variety of factors acting concurrently or separately including nutrition level (Booth et al 1994) or breed (Hunter et al 1993), which differ in the studies reported in the literature.

No differences in LH pulsatility were seen between trials which is in agreement with Smith et al (1991) and Love et al (1993), noting consistent pulsatility throughout the year. Similarly, LH surge duration and peak values did not differ between trials. Inadequate pituitary support has been suggested as the prime mechanism of seasonal abortions and irregular returns to estrus (Peltoneimi et al 1997b). With no observed differences in farrowing rates or subsequent farrowing performance between trials, it

appears that pituitary support of pregnancy remained consistent. Although a consistent seasonal pattern in LH release and activity remains unclear, it is possible that again, by bringing the sows into a short day program, some of these negative seasonal effects on LH that have been documented may have been avoided.

Average daily temperatures in the June and the November trials did not differ and remained in a comfortable range throughout both trials. The main negative effect that temperature appears to exert on a breeding herd is the suppression of appetite due to high ambient temperatures characteristic of the summer months. Higher lactational liveweight losses are usually seen in the summer months, due to an increased rate of mobilization of the sow's body reserves in conjunction with suppressed appetite (Prunier et al 1994). In this study, the sows used in the June trial actually had a significantly greater ADFI than those sows used in the November trial. This is most likely a reflection of the characteristic increase in mobilization of the sows' body reserves, stimulating an increase in appetite, and in the absence of the suppressing effects of high ambient temperature, an increase in ADFI. There is some evidence that younger pigs prefer and perform better under a daily cycle in temperature (as reviewed by Curtis 1983), and it is possible that older pigs, specifically sows, may exhibit this tendency as well. During the June trial, the temperature did have a greater diurnal fluctuation than in the November trial, most likely due to the more exact temperature control with heaters during the fall. A significant increase in lactational weight loss was most likely prevented by the increased ADFI. Additionally, those sows weaned in June weaned larger litters, and a positive correlation was seen between ADFI and number of piglets weaned. This may also

account in part for a greater nutrient mobilization (and partitioning) and ADFI in effort to support a greater number of offspring through milk production.

Mean concentrations of both progesterone and estradiol did not differ between trials. This contrasts to suggestions that an increased rate of clearance during the summer months results in decreased concentrations of estradiol and progesterone (as reviewed by Love et al 1993).

It may be possible that by pooling the data from the two trials, some of the potential effects, advantages, or disadvantages of timed weaning may be masked. However, the negative effects of summer on WEI, ADFI, subsequent litter size, farrowing rate, abortion rate, and endocrine patterns reported throughout the literature did not manifest themselves. It is likely that the use of a short day program 4 weeks before the projected weaning time is capable of preventing these effects.

In those sows blood sampled, all but one appeared to show a consistent hormone pattern complete with estradiol and LH surges. Sow 459G (trial two, weaned AM) displayed standing estrus on day 2 after weaning, was successfully bred and subsequently farrowed. However, no detectable estradiol or LH surge was evident, even though her baseline concentration was comparable to other sows. This may suggest that these surges occurred before sampling commenced. However, the lack of signs or standing estrus on day 1 is puzzling. Further, her subsequent farrowing performance indicates that she was bred at an appropriate time relative to ovulation. It is possible that both surges occurred at such a low concentration the laboratory assays were simply not sensitive enough to determine their occurrence, as complete failure of the assay is unlikely due to both the baseline value as well as the consistent success with the rest of the sampled animals.

Progesterone concentrations were similar to those reported elsewhere (Edwards et al 1983 and Soede et al 1994). A sharp increase in plasma progesterone after estrus and ovulation results from secretion by the new CL (Ash et al 1975). The progesterone profile over time in this study followed this pattern. There was no effect of treatment on progesterone concentration over time, and it appears that timed weaning does not have an effect on progesterone secretion or concentration.

Post-weaning estradiol levels reported in this study are similar, if somewhat lower than those reported by Soede et al (1994) and Hunter et al (1993). There were no differences in the estradiol profile over time between the two treatments, nor were there any differences in estradiol surge activity between treatments. Thus it appears that weaning time does not have an influence on estradiol patterns or profiles.

There was a parity effect on the time from weaning to the beginning of the estradiol surge, as late parity sows (parities 3-6) began their postweaning estradiol surge significantly sooner than early parity sows (parities 1-2). Sesti et al (1993) documented higher levels of estradiol in multiparous sows in mid to late lactation when compared to primaparous sows, as a result of advanced follicular development during this time. This increase in estradiol concentration seen in older sows compared to younger parity sows could also be a reflection of first and second parity sows' need to deposit lean tissue for growth, at the expense of fat deposition (Clowes et al 1994). Johnston et al (1989) determined a negative correlation between body fat and the WEI in primaparous sows. While the early parity sows used in the current trial were not gilts, it seems reasonable to assume that younger sows would also follow this pattern when compared to older sows, and that the advanced follicular activity seen in mid to late lactation is mediated through a

combination of adequate body fat stores and some mechanism of 'mature' ovaries. Further, it seems logical that the advanced follicular activity seen at the end of lactation could result in the estradiol surge beginning sooner after weaning. This may explain the post weaning estradiol surge beginning twice as fast in advanced parity sows.

However, it is of interest to note that there were no significant differences between the early and late parity sows in the maximum estradiol peak value. Nor was there a significant difference in the time from weaning to the peak value of estradiol, although early parity sows had a numerically longer interval. This would seem to indicate that while the early parity sows may begin their surge later, their post weaning follicular activity is capable of some compensatory activity in order to 'catch up' with later parity sows. This theory can be further supported by the observation that early parity sows had a significantly shorter interval between the estradiol peak and the LH peak values. The end result is the occurrence of the LH peak at similar times after weaning across all parities.

There appears to be no effect of weaning time on LH activity. Baseline concentrations, surge duration, maximum peak values, pulsatility, hours from weaning to beginning of LH surge, hours from weaning to LH surge peak, and the interval from the beginning to the peak of the LH surge did not differ between AM- and PM-weaned sows. Values reported for LH activity were similar to those reported by Soede et al (1994) and Diekman et al (1991). Pulsatility of LH was similar to values reported by Diekman et al (1991) using a sampling frequency of 30 min. While the overall number of LH pulses reported was greater for PM-weaned sows, it is important to note that the number of pulses per sampling period did not differ between treatments. PM-weaned sows had a

longer WEI, and though not statistically different, it resulted in a longer sampling period during which additional LH pulses were determined. It appears that weaning either immediately after lights-on or immediately before lights-out does not have an effect on LH activity.

The timing of LH pulsatility for both the AM- and PM-weaned sows throughout the light-dark cycles followed a very similar pattern. There were no significant differences between treatments for the number of pulses occurring during either the dark or the light phase. The patterns of LH pulses occurring throughout the sampling period did not match those observed by Elsaesser (1982), who reported that the majority of LH pulses occur during the night and early morning hours. Nor was the data in agreement with the report by Evans et al (1996), who observed sows weaned two hours after lights-on exhibited a greater number of peaks during the light hours of the light-dark cycle than those sows weaned later in the day relative to lights-on. In the current study, the majority of the observed pulses for both treatments occurred during the light hours, however it is important to note that between 0100h and 0800h, samples were collected at 60 minute intervals, which may have resulted in some pulses being missed during this time. Regardless of this, the profiles of observed LH pulses for both treatments followed a very similar pattern at all times. The data reported by Evans et al (1996) used sows housed under a long-day photoperiod, suggesting that the use of an optimal short-day photoperiod may synchronize the LH pulsatility via some mechanism, regardless of weaning time relative to lights-on.

There was a significant difference between treatments in the time of day (light - dark cycle) at which the estradiol surge started. There was no difference between

treatments in the interval from weaning to the beginning of the estradiol surge. Thus the start of the estradiol surge in AM-weaned sows occurred more often in the scotoperiod.

Positive correlations were found between the interval from weaning to peak estradiol, the interval from weaning to peak LH and WEI, regardless of treatment, confirming that these parameters are closely associated. The peak of the LH surge occurs at approximately 8-15 hours after the peak of the estradiol surge (Foxcroft and van de Weil 1982). Similar intervals were recorded in the current trial with mean values approximating the 15 hour mark. As with WEI, PM-weaned sows also had greater variation in the interval from the estradiol surge to the LH peak. This would suggest that the occurrence of the LH peak would occur in a more synchronized grouping in the AM-weaned sows with respect to the occurrence of the estradiol surge. However, in actuality, there was no difference in the variability in either the interval from weaning to the estradiol peak or weaning to LH peak. The interval from weaning to the estradiol peak were virtually identical for both treatments, however AM-weaned sows had a greater but non-significant interval from weaning to the LH peak. This difference may be the reason for the significant variation between AM and PM-weaned sows in the interval from peak estradiol to peak LH.

The time of the light-dark cycle during which the peak of the LH surge occurred was significantly different between treatments. In the AM-weaned sows the LH peak values occurred almost exclusively between 1700h and 0800 (dark) (with the majority occurring between 1900h and 2400h). The LH peak values for PM-weaned sows were scattered throughout the light and dark periods. The synchrony observed in the AM-weaned sows in the timing of the LH surge relative to the estradiol surge may also relate

to the greater synchrony observed in their WEI. By knowing the approximate time that the LH surge will take place, it is possible to estimate time of ovulation. Ovulation occurs approximately 30 hours after the LH peak (Soede et al 1994), and it has been suggested that insemination 0-24 hours prior to ovulation results in successful fertilization (Soede et al 1994). At the time of the estradiol peak, the sow should be showing signs of estrus due to high estradiol concentrations (Hafez 1993) A more precise prediction when the LH peak, ovulation, and the timing of the 24 hour optimal insemination window is possible based on the onset of estrus.

The majority of the sampled sows, regardless of treatment, displayed first signs of behavioural estrus in the interval from 0800h and 1200h. This is most likely a combination of those sows that did begin to display estrus during this time, as well as sows who began to come into estrus during the night. While care was taken to observe sows throughout the night, it is possible that some first signs of estrus were missed in the dark at which time vision was difficult and there was no boar exposure. In some cases, signs of estrus only became evident upon boar exposure, which was carried out during the interval from 0800h to 1200h. These factors together most likely explain the large number of sows that appeared to show first signs of estrus during this interval.

A predictable positive correlation existed between number of piglets born alive and litter birth weight, as well as an expected positive correlation between hours from weaning to signs of estrus and WEI. In contrast to data reported by Vesseur et al (1994) and Kemp et al (1996), no negative correlation between WEI and subsequent litter size and farrowing rate was found. One of the reasons suggested for this phenomenon is that sows with longer WEI display shorter estrus periods, resulting in sows being missed

during routine heat checks, or inseminated at suboptimal times. In the current study, it is possible that this was avoided due to the multiple estrus checks and observation of the sows in contrast to large commercial units where estrus detection is usually done once a day.

There were significant endocrine correlations within treatments and for pooled data of all sampled sows. A positive correlation between hours from weaning to both the estradiol surge and the LH surge and WEI was observed for both treatments, indicating that these events are closely linked outside of external influence. A positive correlation was evident between estradiol surge duration and the baseline concentration of LH for both treatments. Foxcroft et al (1987) saw positive correlations between number and diameter of estrogenic follicles and basal LH concentrations. Based on this data, the longer estrogen surge seen in those sows having higher baseline LH concentrations may be the result of a greater number and size of developing follicles immediately after weaning.

Foxcroft et al (1987) further suggested that higher baseline concentrations are associated with, and may be the stimulus for a more rapid development of follicles and an earlier return to estrus. A shorter WEI would be expected in those sows having higher baseline concentrations of LH. However, this seems unlikely in the current trial as those sows having higher LH baseline concentrations had a longer (though not significant) WEI regardless of treatment. Additionally, sows displaying higher baseline LH concentrations did not have a significantly greater litter birth size, suggesting that the number of developing follicles was not greater than in those sows having lower LH baseline

concentrations. It appears that higher baseline concentrations of LH do not hasten WEI but seem to impair or interfere with a rapid return to estrus.

Time of weaning relative to the onset of lights-on or lights-off did play a role in the synchrony of the WEI, as evident by the significant variation in the WEI between treatments. While endocrine patterns did not differ in concentration or activity in response to timed weaning, the timing of the profiles was altered. This may facilitate a better prediction of ovulation and thus an optimal insemination time in the sow.

CHAPTER 6

CONCLUSIONS

In this study, there was no difference in the duration of the WEI between sows weaned at 0800h (AM) when lights came on and those sows weaned at 1645h (PM) immediately before lights-off. However, the synchrony with which the sows returned to estrus was different between treatments. AM-weaned sows returned to estrus in a more synchronized group than PM-weaned sows, supporting our hypothesis. This indicates that the time of weaning has some influence on WEI. Time of weaning did not appear to have any effect on rebreeding or subsequent farrowing performance.

No seasonal effects were seen on WEI, rebreeding performance, or subsequent farrowing performance, and, with the exception of overall mean baseline concentrations of LH being higher in the June trial, no seasonal effects on endocrine profiles were observed. This lack of seasonal effects on both reproductive performance and endocrine profiles could be due to the short-day light program under which all sows were kept four weeks prior to weaning.

While treatment appeared to have little effect on overall endocrine concentrations, the timing of the profiles differed between treatments. In AM-weaned sows, the estradiol surge began in the scotoperiod more often and less variation in the time from the estradiol

peak to the LH peak was observed. Further, the LH peak occurred almost exclusively during the scotoperiod (with the majority occurring between 1900h and 2400h), while the LH peak values for PM-weaned sows were scattered throughout the sampling period. Thus, prediction of the time of ovulation should be more consistent in AM-weaned sows, facilitating optimal insemination timing of a greater number of sows. Positive correlations that were observed between hours from weaning to both the estradiol and the LH surge and WEI reaffirm that these endocrine events are closely linked to WEI regardless of external influence. These results further support our hypothesis of a endocrine profile that may facilitate insemination at an optimal time in those sows weaned at 0800h.

Further research is recommended to examine the role that other hormones, such as melatonin, may have in influencing endocrine profiles and subsequent reproductive performance. Exposure to a short-day light program four weeks prior to weaning appeared to be able to correct for any seasonal influences previously documented on endocrine profiles and reproductive performance. Additional hormone analysis would be useful to determine any masking effect that season may have on timing of weaning. Further, the use of ultrasound techniques would be beneficial in determining the effect that timing of weaning may have on ovulation rates, allowing an accurate measurement of embryo survival.

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APPENDIX

TABLE A1. Mean serum concentrations of progesterone (ng/ml) in AM and PM weaned sows

Event	Treatment*		
	AM	PM	P
Day of weaning	0.30± 0.14	0.24± 0.21	0.9830
Day after weaning	0.45± 0.14	0.27± 0.15	0.7113
Day before standing estrus	0.32± 0.14	0.35± 0.17	0.7900
Day of standing estrus	0.61± 0.17	0.49± 0.17	0.8571
Day after standing estrus	1.14± 0.16	1.05± 0.20	0.9379

*values are least squares means±standard error of the means

TABLE A2. Mean serum concentrations of estradiol (pg/ml) in AM (n=9) and PM (n=9) weaned sows

Event	Treatment*		
	AM	PM	P
Day of weaning	3.04± 0.82	2.07±1.18	0.6507
Day after weaning	6.03± 0.82	4.13± 0.82	0.6127
Day before standing estrus	10.14± 0.80	8.49± 0.95	0.7174
Day of standing estrus	7.54± 0.94	4.27± 0.99	0.2445
Day after standing estrus	2.98± 0.93	2.49± 1.11	0.8103

*values are least squares means±standard error of the means

TABLE A3. Mean serum concentrations of LH (ng/ml) in AM and PM weaned sows

Event	Treatment*		
	AM	PM	P
Day of weaning	1.06± 0.37	0.54± 0.46	0.5000
Day after weaning	2.59 ±0.80	1.74± 0.37	0.7955
Day before standing estrus	1.28 ±0.80	1.30± 0.79	0.7128
Day of standing estrus	1.34 ±0.78	1.44± 0.81	0.6684
Day after standing estrus	1.20 ±0.78	0.61± 0.61	0.9690

*values are least squares means±standard error of the means

TABLE A4. Significant correlations and trends for AM weaned sows. 'Estrus' refers to first standing estrus

Correlation**	r	P
LH surge maximum peak value and LH baseline concentration	0.87759	0.0094
E2 surge maximum peak value and LH surge duration	0.79786	0.0315
E2 surge duration and LH surge maximum peak value	0.76770	0.0439
LH baseline concentration and hours from weaning to standing estrus	0.72668	0.0266
LH surge max. peak value and hours from weaning to standing estrus	0.77178	0.0421
E2 surge duration and hours from weaning to standing estrus	0.86017	0.0130
LH surge maximum peak value and number of stillborn per litter	-0.8300	0.0409
LH concentration on the day of weaning and hours from weaning to estrus	0.72687	0.0265
LH concentration on the day after weaning and hours from weaning to estrus	0.74236	0.0220
P4 concentration day of estrus and hours from weaning to estrus	0.69529	0.0376
P4 concentration day after weaning and hours from weaning to estrus	-0.7826	0.0161
E2 concentration on the day of estrus and litter birth weight	-0.7826	0.0217
Number born alive per litter and litter birth weight	0.87461	0.0045
[LH] day of weaning and [LH] day after weaning	0.87240	0.0022
[LH] day of weaning and [LH] day before estrus	0.75509	0.0187
[LH] day after weaning and [LH] day before estrus	0.82848	0.0058
[LH] day of weaning and [LH] day after estrus	0.70203	0.0350
[LH] day after weaning and [LH] day after estrus	0.79437	0.0105
[LH] day before estrus and [LH] day after estrus	0.81731	0.0071
[E2] day of weaning and [P4] day of weaning	-0.7279	0.0262
[E2] day after weaning and [P4] day after weaning	0.70756	0.0330
[E2] day before estrus and [P4] day after weaning	-0.8000	0.0096
[E2] day before estrus and [P4] day after estrus	-0.8080	0.0084
[P4] day of weaning and [P4] day before estrus	0.76755	0.0157
[P4] day after weaning and [P4] day of estrus	0.82284	0.0064
[P4] day of estrus and [P4] day after estrus	0.87932	0.0018
Hours from weaning to start of LH surge and hours from weaning to estrus	0.86499	0.0119
Hours from weaning to LH peak and hours from weaning to estrus	0.89209	0.0069

Hours from weaning to LH peak and hours from weaning to E2 peak	0.98112	0.0001
Hours from weaning to LH peak		
Hours from weaning to LH peak and hours from weaning to start of LH surge	0.97724	0.0001
Hours from weaning to start of E2 surge and number of mummies per litter	0.92686	0.0078
Hours from weaning to E2 peak and hours from weaning to estrus	0.95454	0.0008
Hours from weaning to E2 peak and hours from weaning to start of LH surge	0.96328	0.0005
Interval(h) from start to peak of E2 surge and hours from weaning to estrus	0.80703	0.0282
Interval(h) from start to peak of E2 surge and hours from weaning to start of LH surge	0.92255	0.0031
Interval(h) from start to peak of E2 surge and hours from weaning to LH peak	0.96686	0.0004
Hours from weaning to first signs of estrus and [P4] day after weaning	-0.7801	0.0131
Hours from weaning to first signs of estrus and [P4] day after estrus	-0.7200	0.0287
Trend*	**r**	**P**
E2 surge duration and LH baseline concentration	0.74146	0.0565
E2 surge duration and litter weight	-0.7385	0.0936
LH concentration the day before estrus and hours from weaning to estrus	0.58326	0.0978
LH concentration the day after first standing estrus and hours from weaning to estrus	0.62020	0.0748
E2 concentration day after weaning and hours from weaning to estrus	0.63102	0.0684
P4 concentration day after estrus and hours from weaning to estrus	-0.6022	0.0861
[LH] day of estrus and [E2] day after weaning	0.65485	0.0556
[E2] day after weaning and [P4] day after estrus	0.63513	0.0661
[E2] day after estrus and [P4] day before estrus	-0.6433	0.0616
Hours from weaning to start of LH surge and number born alive per litter	-0.7296	0.0998
Hours from weaning to first signs of estrus and LH pulsatility	-0.5846	0.0983
Hours from weaning to start of LH surge and litter birth weight	-0.0729	0.0998

**significant at P<.05
* significant at P<.10

TABLE A5. Significant correlations and trends for PM weaned sows. 'Estrus' refers to first standing estrus.

Correlation**	r	P
LH surge duration and LH surge max. value	0.92974	0.0026
LH baseline concentration and E2 surge duration	0.86536	0.0119
Number born alive per litter and litter birth weight	0.90107	0.0022
Stillborn per litter and [P4] day of weaning	0.83028	0.0107
Stillborn per litter and [P4] day after weaning	0.84174	0.0088
Stillborn per litter and [P4] day before estrus	0.73803	0.0365
Stillborn per litter and [P4] day after estrus	0.86752	0.0053
Stillborn per litter and [LH] day after weaning	0.70849	0.0492
Stillborn per litter and [LH] day before estrus	0.75578	0.0301
[LH] day after estrus and hours from weaning to estrus	0.79524	0.0104
[LH] day before estrus and [LH] day after weaning	0.90547	0.0008
[LH] day of estrus and [E2] day of estrus	0.68280	0.0427
[LH] day before estrus and [P4] day after estrus	0.75996	0.0175
[E2] day of estrus and [E2] day after estrus	0.76446	0.0164
[P4] day of weaning and [P4] day of estrus	0.68234	0.0429
[P4] day of weaning and [P4] day after weaning	0.88940	0.0013
[P4] day after weaning and [P4] day of estrus	0.69925	0.0361
[P4] day before estrus and [P4] day of estrus	0.91651	0.0005
[E2] day before estrus and [P4] day before estrus	0.75996	0.0175
[E2] day after weaning and [P4] day after estrus	0.89049	0.0030
Hours from weaning to start of LH surge and number stillborn per litter	-0.7568	0.0297
Hours from weaning to LH peak and hours from weaning to estrus	0.77965	0.0225
Hours from weaning to LH peak and hours from weaning to start of LH surge	0.97544	0.0001
Interval(h) from start to peak of LH surge and number stillborn per litter	0.77334	0.0244
Hours from weaning to E2 peak and hours from weaning to start of LH surge	0.73534	0.0376
Hours from weaning to E2 peak and hours from weaning to estrus	0.84355	0.0085
Hours from weaning to first signs of estrus and hours from weaning to estrus	0.8943	0.0011

Hours from weaning to first signs of estrus and [LH] day of weaning	-0.6836	0.0424
Hours from weaning to first signs of estrus and [LH] day after estrus	0.70071	0.0355
Trend*	**r**	**P**
LH baseline concentration and hours from weaning to estrus	0.63239	0.0676
LH baseline concentration and hours from weaning to first standing estrus	0.66265	0.0518
LH surge max. value and number of still born per litter	0.69610	0.0551
LH surge duration and number of stillborn per litter	0.75420	0.0501
LH baseline concentration and number of mummies per litter	0.66005	0.0749
Number born alive per litter and hours from weaning to estrus	0.69850	0.0540
Litter birth weight and hours from weaning to estrus	0.66112	0.0742
Stillborn per litter and [E2] day before estrus	0.62767	0.0957
Stillborn per litter and [P4] day of estrus	0.64157	0.0864
Born alive per litter and [LH] day of estrus	-0.6467	0.0831
[LH] day of weaning and hours from weaning to estrus	-0.6501	0.0580
[E2] day after weaning and [P4] day of estrus	0.70579	0.0504
[E2] day after weaning and [E2] day before estrus	0.66643	0.0711
[E2] day after weaning and [P4] day before estrus	0.66442	0.0723
[E2] day of weaning and [E2] day before estrus	-0.6384	0.0641
[E2] day before estrus and [P4] day after weaning	0.60430	0.0848
[E2] day after estrus and [P4] day of weaning	0.60690	0.0831
Hours from weaning to start of LH surge and hours from weaning to estrus	0.62904	0.0947
Hours from weaning to LH peak and number stillborn per litter	-0.6940	0.0562

* ** significant at P<.05
* * significant at P<.10

TABLE A6. Significant correlations and trends for all sampled AM and PM weaned sows (combined data set). 'Estrus' refers to first standing estrus.

Correlation**	r	P
LH surge duration and LH surge max. peak value	0.79427	0.0007
LH baseline concentration and E2 surge duration	0.71327	0.0042
Hours from weaning to estrus and E2 surge duration	0.62375	0.0171
Number born alive per litter and litter birth weight	0.88302	0.0001
[LH] day of weaning and [LH] day after weaning	0.71710	0.0008
[LH] day of weaning and [LH] day after estrus	0.71732	0.0008
[LH] day after weaning and [LH] day before estrus	0.80823	0.0001
[LH] day after weaning and [LH] day after estrus	0.53215	0.0230
[E2] day before estrus and [E2] day after weaning	0.70775	0.0015
[P4] day of weaning and [P4] day before estrus	0.75495	0.0003
[P4] day of weaning and [P4] day of estrus	0.54045	0.0206
[P4] day after weaning and [P4] day of estrus	0.78165	0.0001
[P4] day of estrus and [P4] day after estrus	0.66185	0.0028
[P4] day after weaning and [P4] day after estrus	0.87079	0.0001
[P4] day of weaning and [E2] day of weaning	-0.4696	0.0493
[LH] day before estrus and number of mummies per litter	0.50707	0.0450
Hours from weaning to estrus and [P4] day of estrus	-0.4958	0.0364
Hours from weaning to estrus and [P4] day after weaning	-0.4885	0.0395
Number of mummies per litter and [LH] day before estrus	0.50707	0.0450
Hours from weaning to start of LH surge and hours from weaning to estrus	0.62021	0.0136
Hours from weaning to LH peak and hours from weaning to estrus	0.76904	0.0008
Hours from weaning to LH peak and hours from weaning to start of LH surge	0.96363	0.0001
Hours from weaning to start of LH surge and interval (h) from start to peak of LH surge	-0.8127	0.0002
Hours from weaning to E2 peak and hours from weaning to estrus	0.88978	0.0001
Hours from weaning to E2 peak and hours from weaning to start of LH surge	0.76620	0.0009
Hours from weaning to E2 peak and hours from weaning to LH peak	0.88268	0.0001
Hours from weaning to E2 peak and interval (h) from start to peak of E2	0.56123	0.0295

surge		
Interval (h) from start to peak of E2 surge and hours from weaning to estrus	0.61831	0.0140
Interval (h) from start to peak of E2 surge and hours from weaning to LH peak	0.58003	0.0234
Interval (h) from start to peak of LH surge and hours from weaning to LH peak	-0.6274	0.0123
Hours from weaning to estrus and hours from weaning to first signs of estrus	0.76231	0.0002
Trend*	r	P
Hours from weaning to first signs of estrus and [P4] day after weaning	-0.4505	0.0606
Hours from weaning to first signs of estrus and [P4] day after estrus	-0.4643	0.0522
[LH] day of weaning and [LH] day before estrus	0.42536	0.0784
[E2] day after weaning and [E2] day of estrus	0.46284	0.0614
[E2] day before estrus and [E2] day of estrus	0.44198	0.0663
[E2] day of estrus and [E2] day after estrus	0.40837	0.0925
[E2] day before estrus and [E2] day after estrus	0.43624	0.0703
[P4] day of weaning and [P4] day after weaning	0.40316	0.0971
[P4] day before estrus and [LH] day before estrus	0.42738	0.0769
[P4] day before estrus and [E2] day of weaning	-0.4499	0.0610
Number born alive per litter and [LH] day before estrus	0.46691	0.0683
Number of mummies per litter and [LH] day after weaning	0.48405	0.0574
Number of stillborn per litter and [E2] day before estrus	0.48435	0.0573
Number of stillborn per litter and [P4] day of weaning	0.46846	0.0672
Hours from weaning to estrus and [P4] day after estrus	-0.4509	0.0604
Hours from weaning to start of LH surge and number stillborn per litter	-0.5077	0.0638

** significant at P<.05
* significant at P<.10

TABLE A7. T-test procedure for WEI (h) in AM and PM weaned sows

Treatment	n	Mean	Std Dev	Std Error
AM	42	99.59	27.89	4.30
PM	42	106.63	42.25	6.52

Variances	T	DF	Prob>T
Unequal	-0.9005	71.0	0.3709
Equal	-0.9005	82.0	0.3705

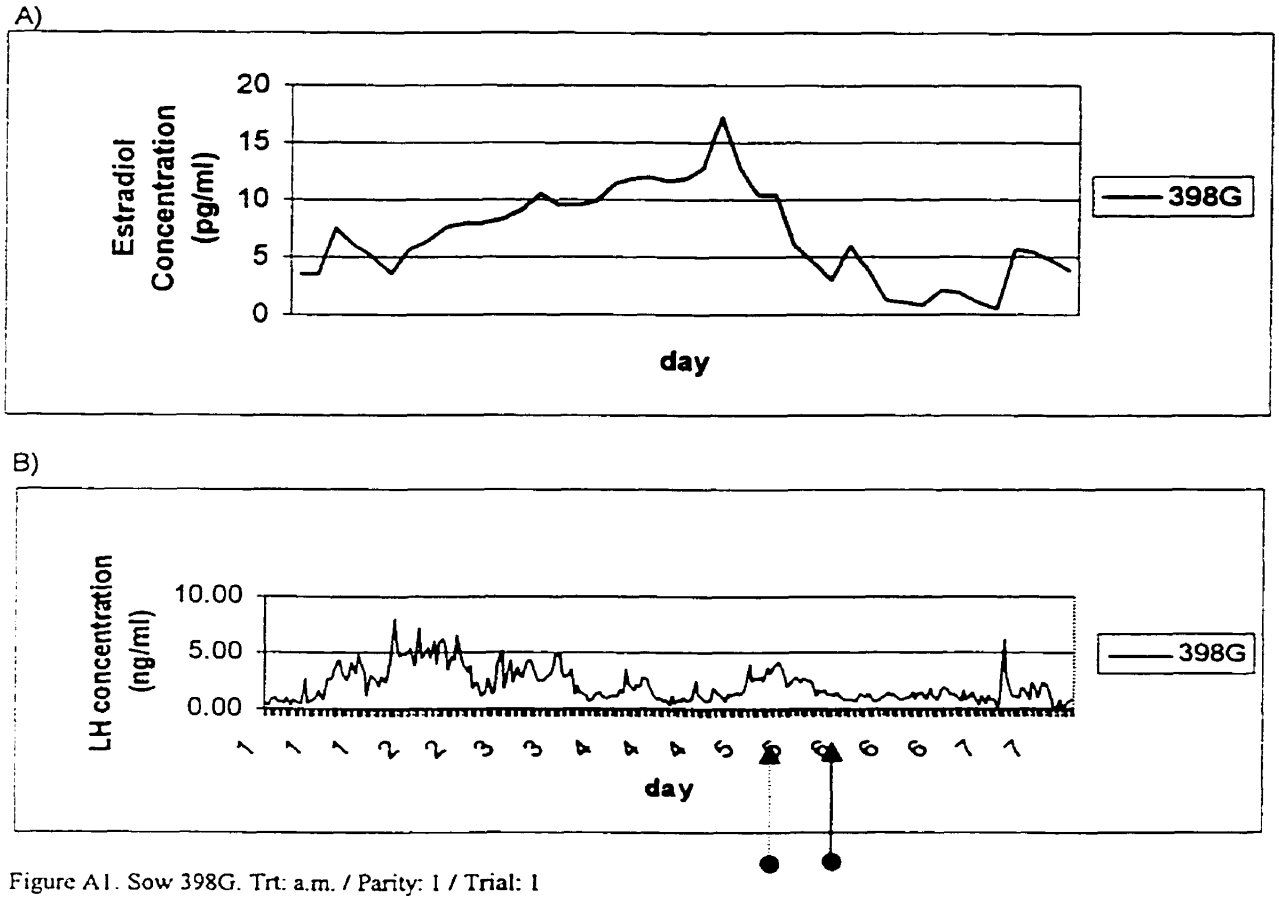


Figure A1. Sow 398G. Trt: a.m. / Parity: 1 / Trial: 1

Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus

standing estrus

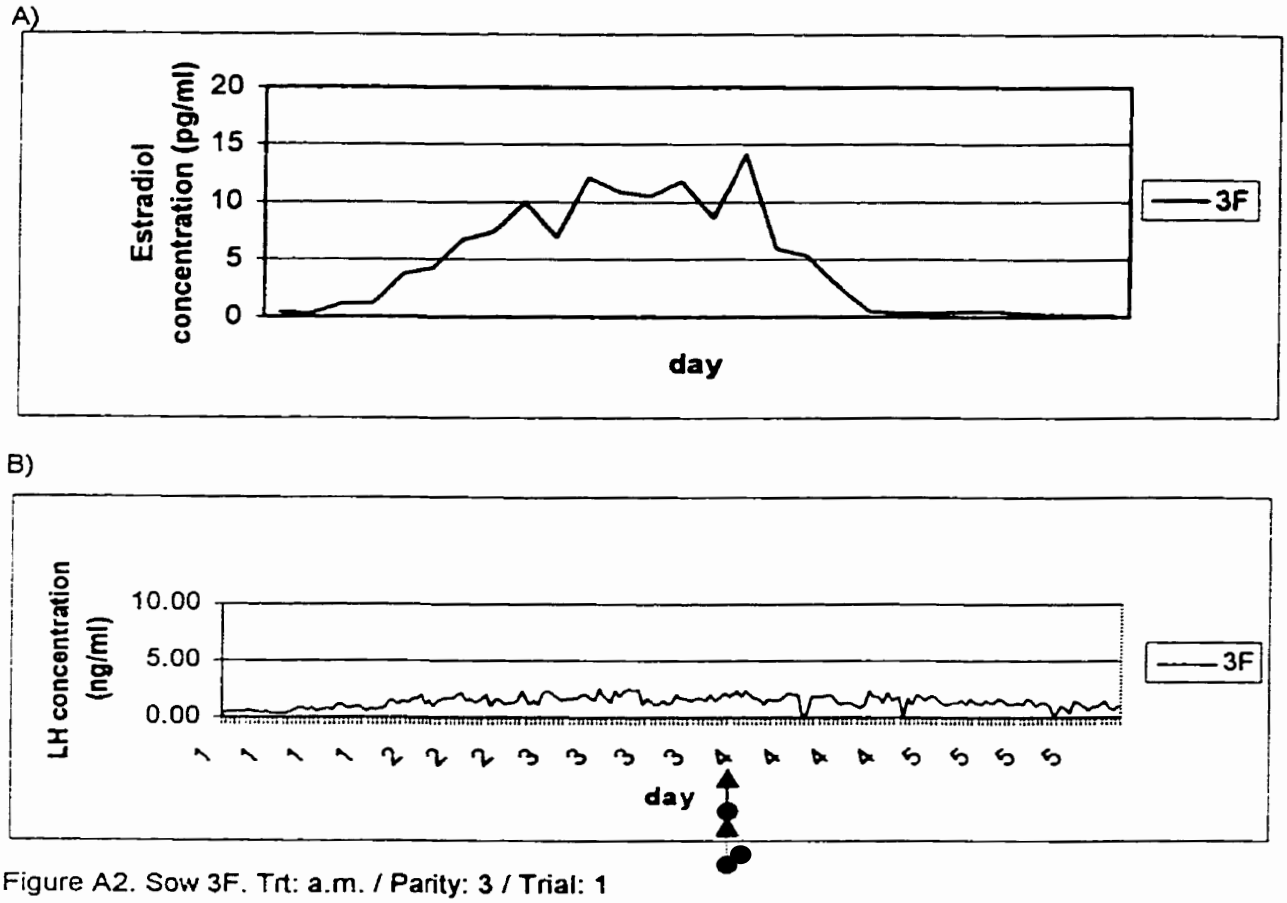
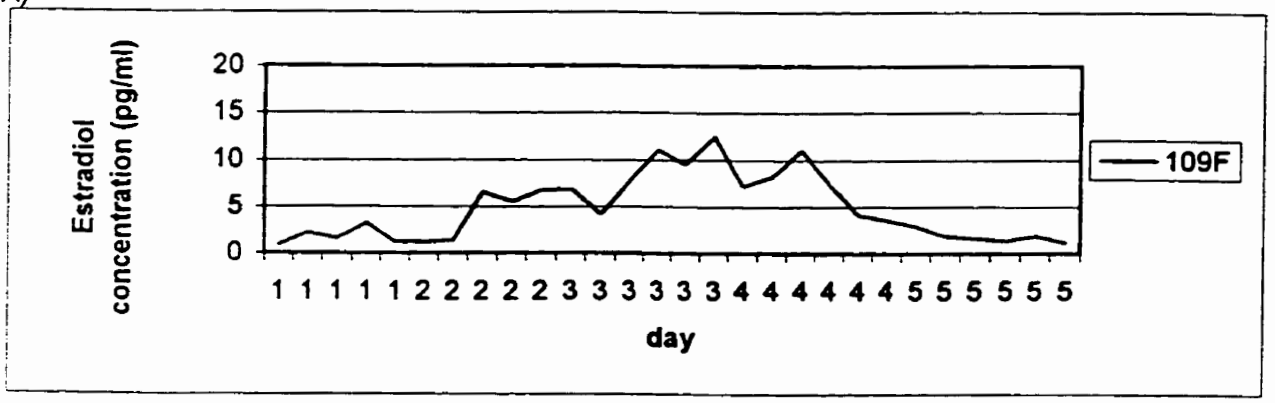


Figure A2. Sow 3F. Trt: a.m. / Parity: 3 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

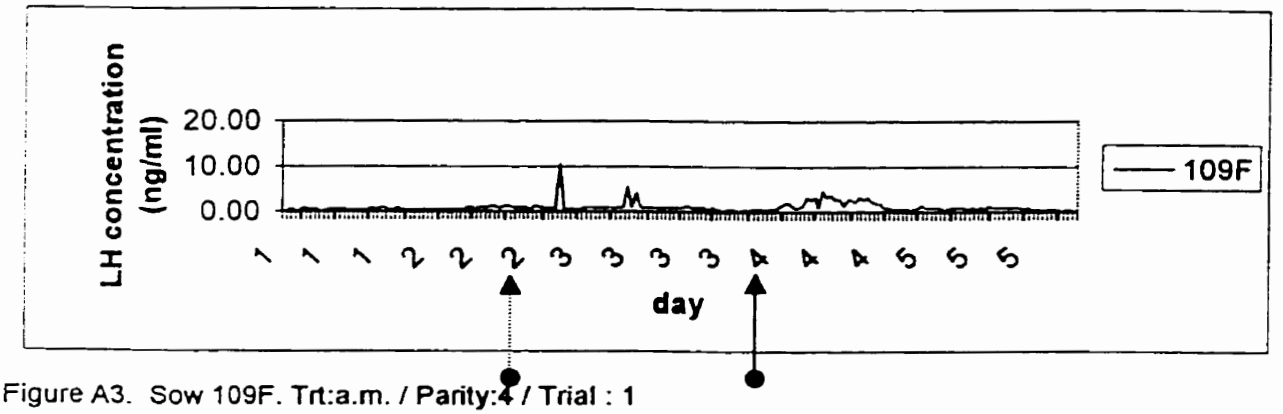
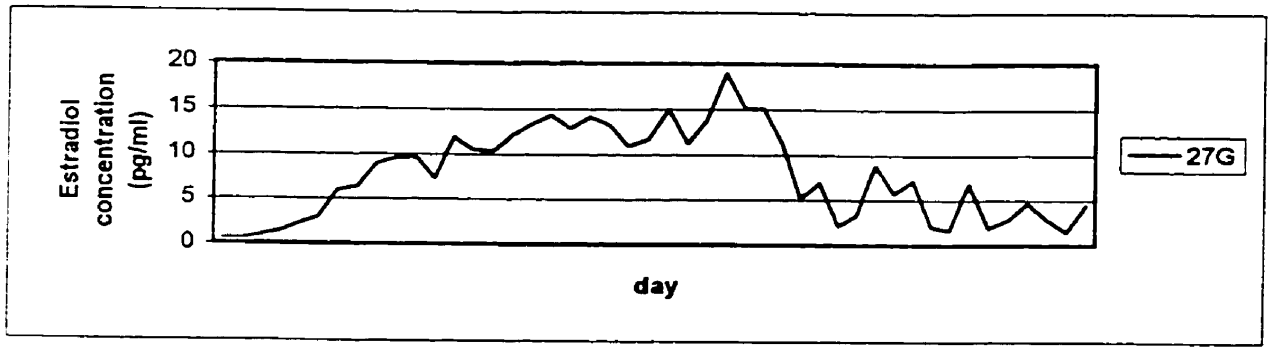


Figure A3. Sow 109F. Trt:a.m. / Parity:4 / Trial : 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

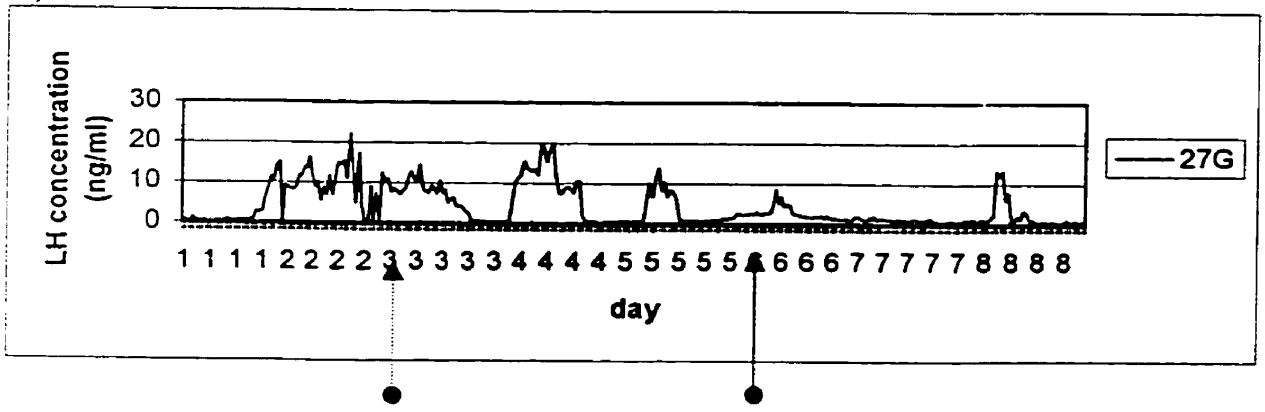
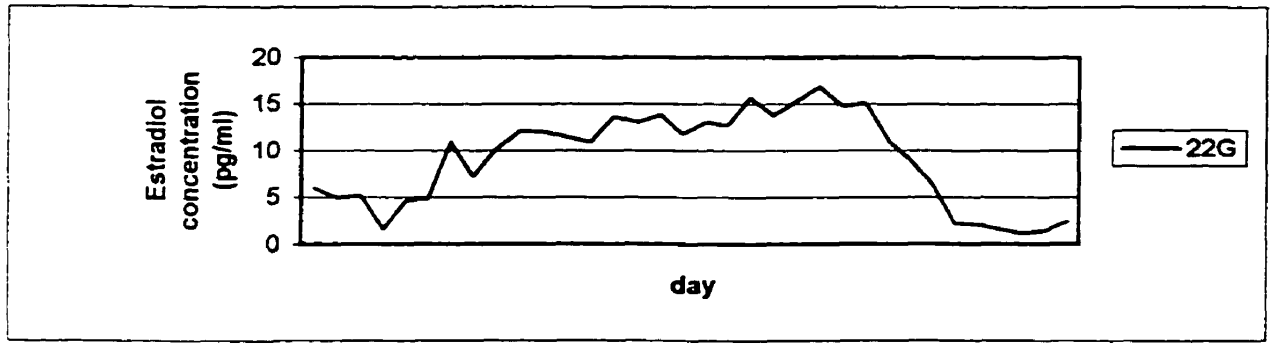


Figure A4. Sow 27G. Trt: a.m. / Parity: 2 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

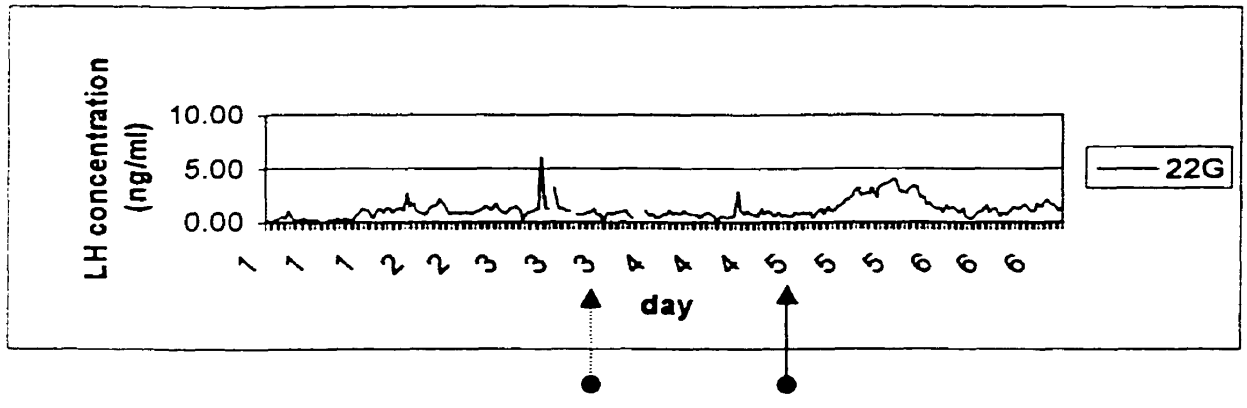
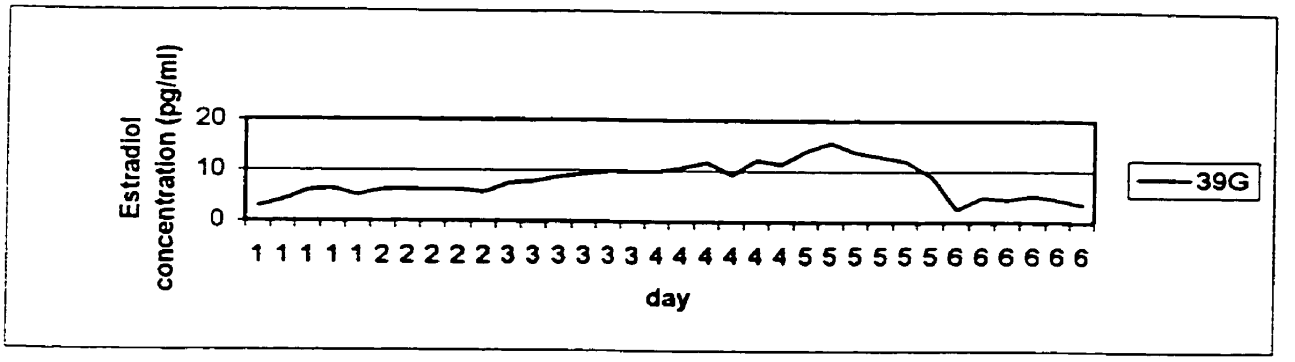


Figure A5. Sow 22G. Trt: a.m. / Parity: 3 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

●⋯▶ signs of estrus
●—▶ standing estrus

A)



B)

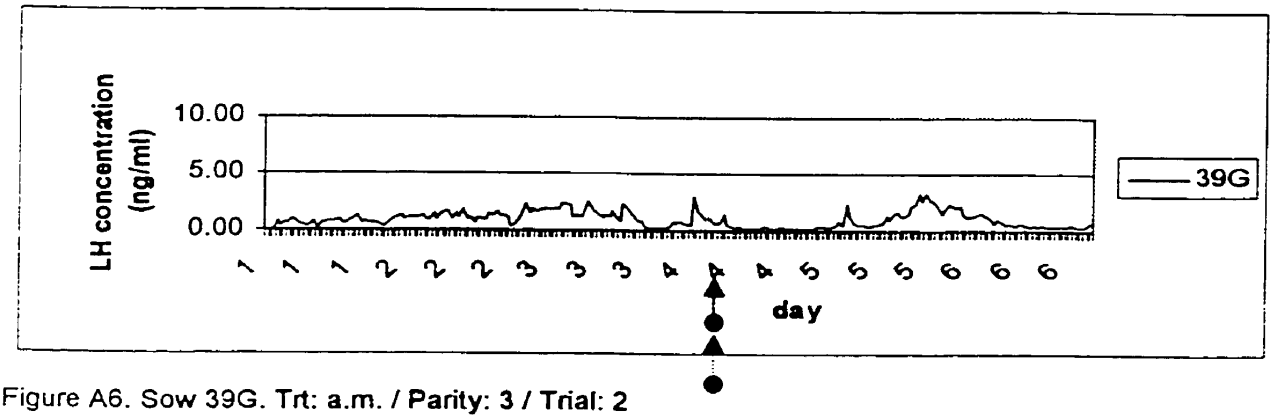


Figure A6. Sow 39G. Trt: a.m. / Parity: 3 / Trial: 2
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

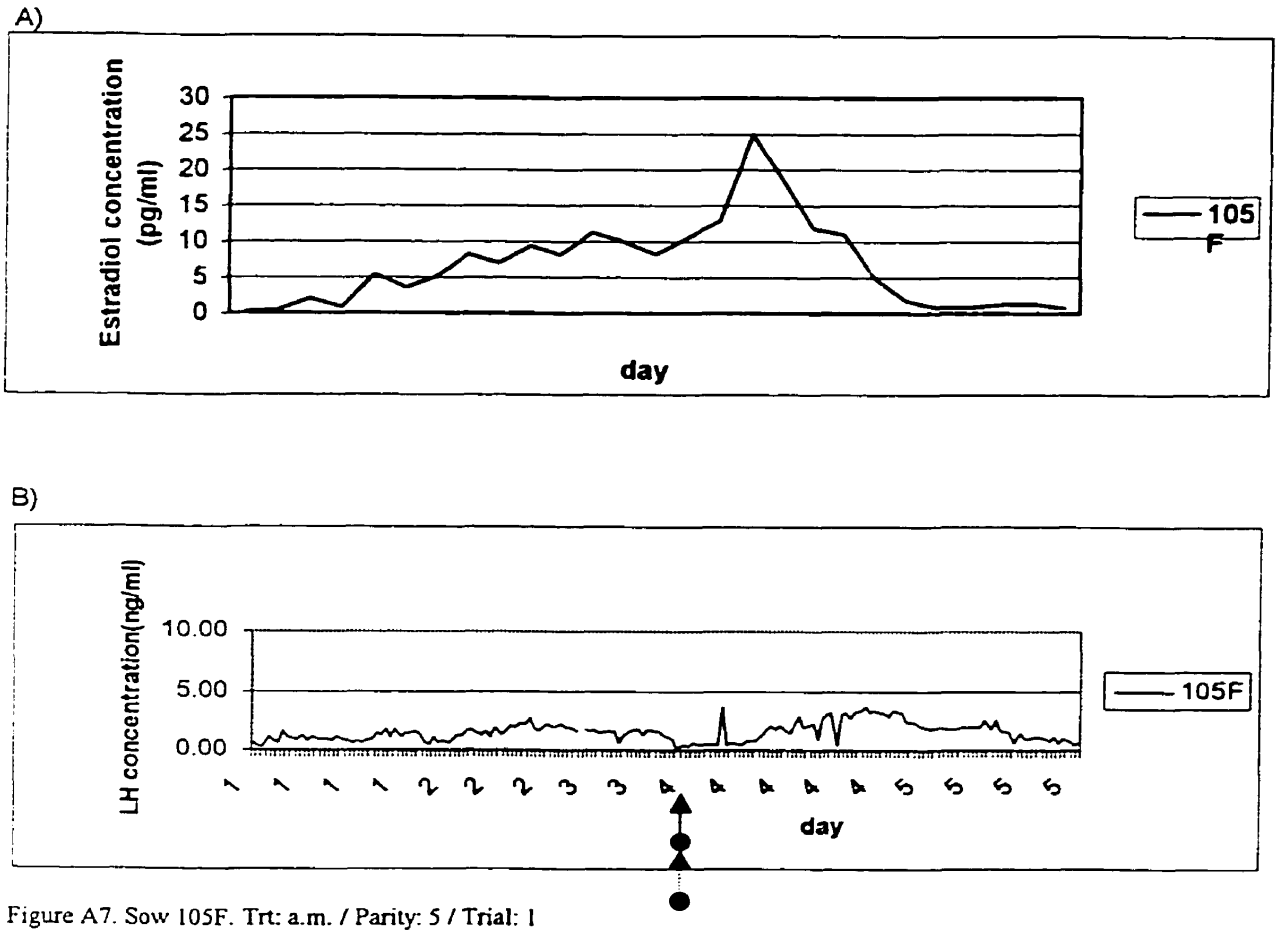


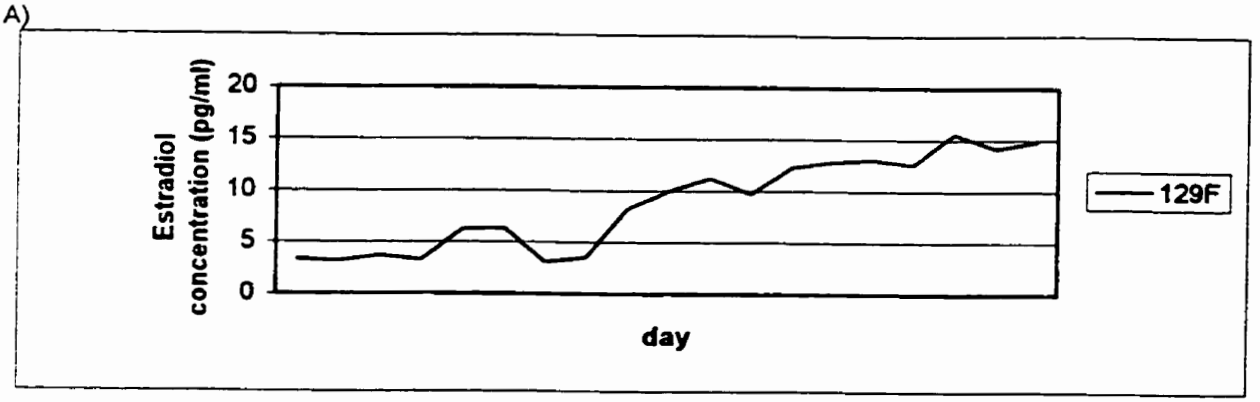
Figure A7. Sow 105F. Trt: a.m. / Parity: 5 / Trial: 1

Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus

standing estrus

A)



B)

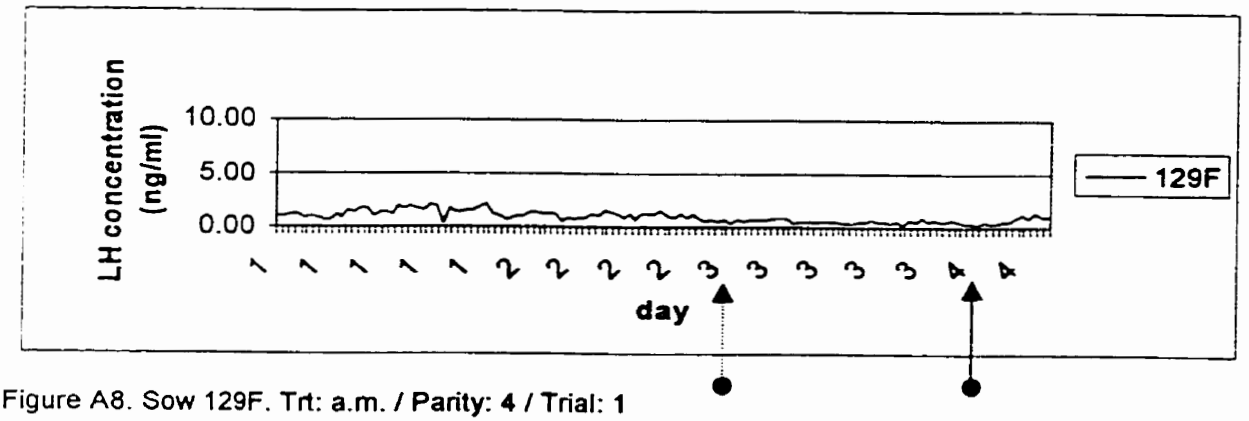
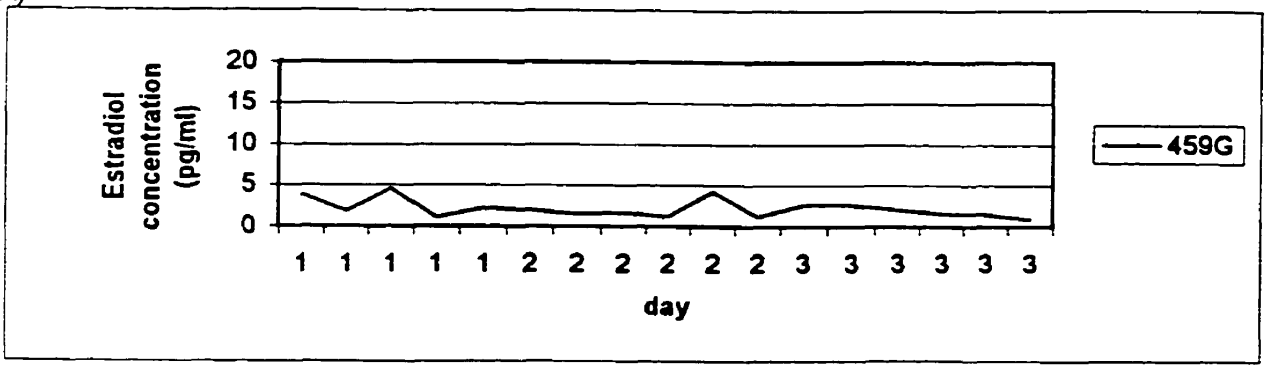


Figure A8. Sow 129F. Trt: a.m. / Parity: 4 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

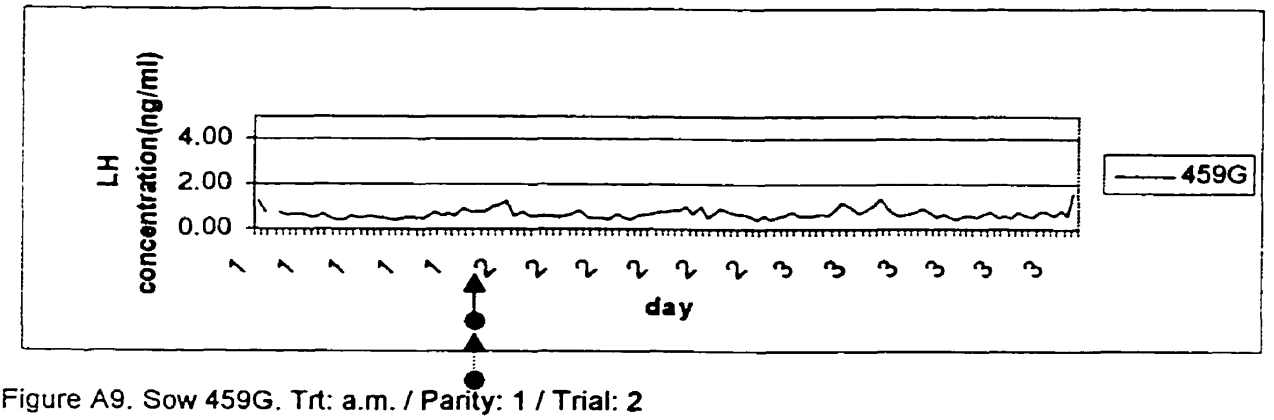
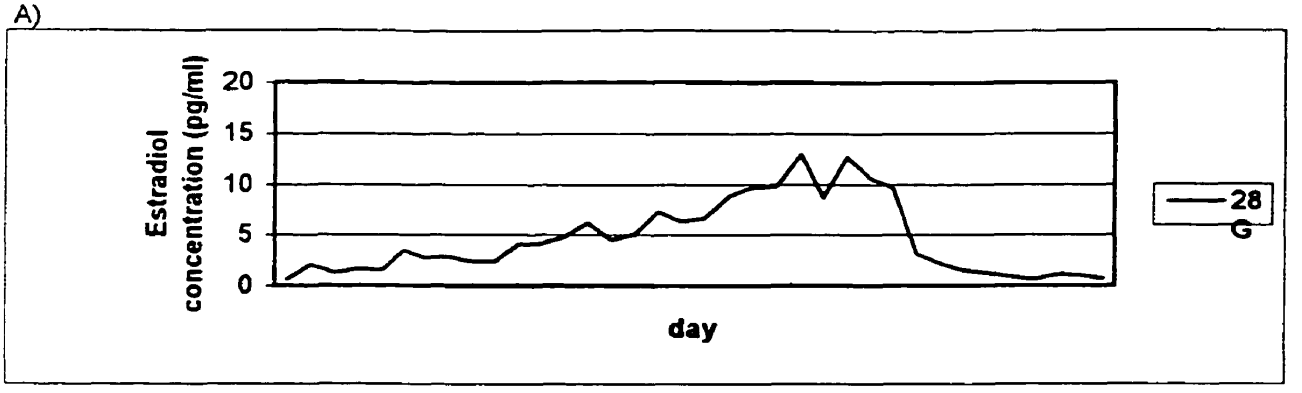


Figure A9. Sow 459G. Trt: a.m. / Parity: 1 / Trial: 2
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

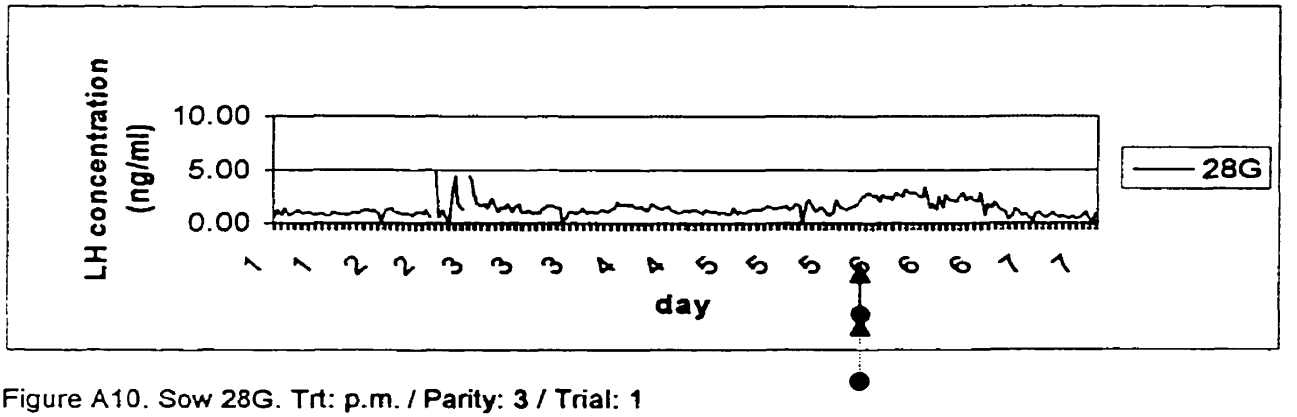


Figure A10. Sow 28G. Trt: p.m. / Parity: 3 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

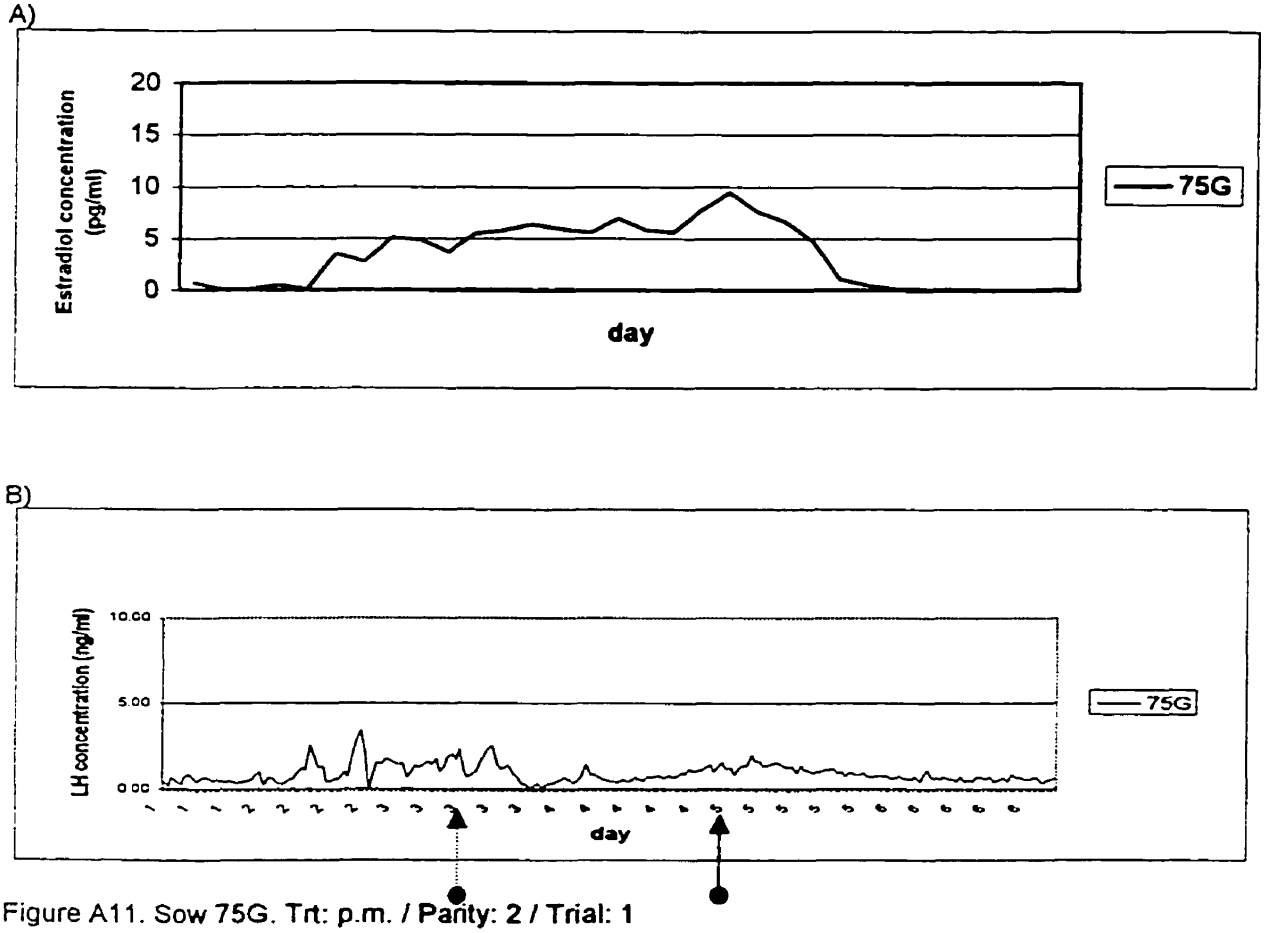
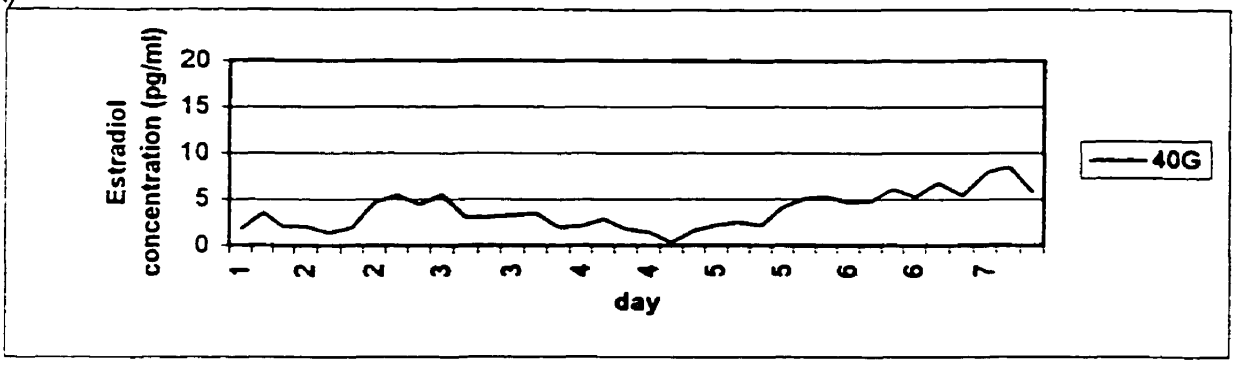


Figure A11. Sow 75G. Trt: p.m. / Parity: 2 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

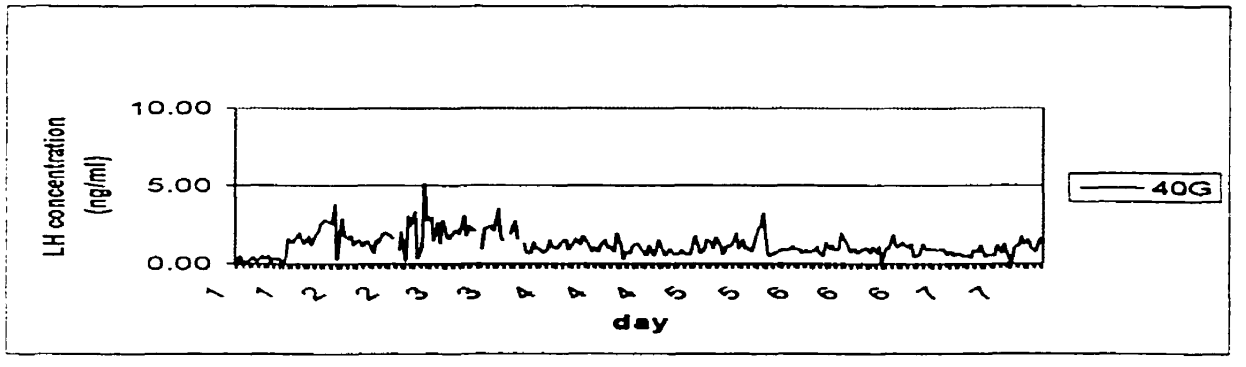


Figure A12. Sow 40G. Trt: p.m. / Parity: 3 / Trial: 1 (note: first standing heat on day 10 / 208.25 hrs after weaning. No signs of heat prior to standing heat)
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

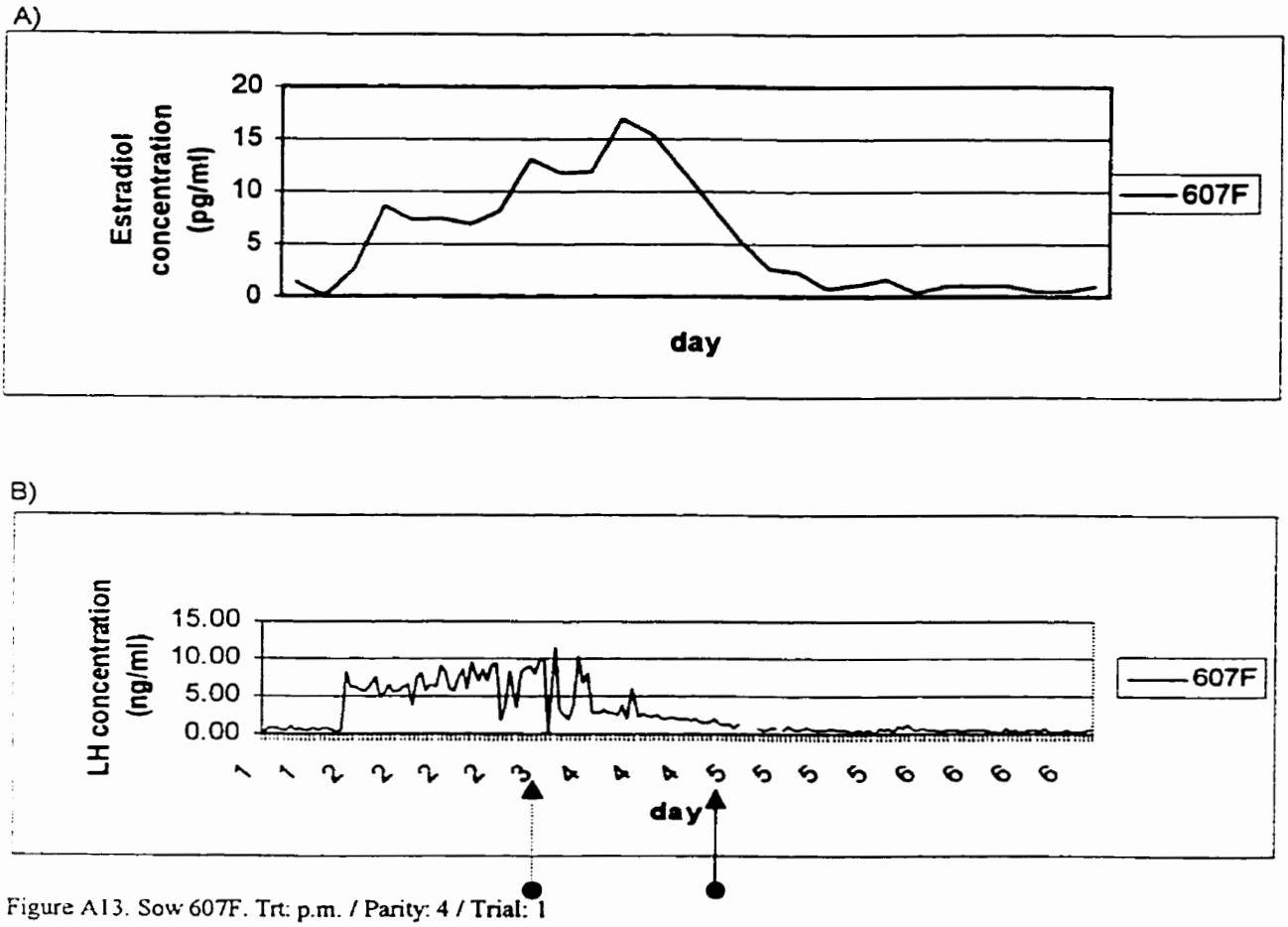


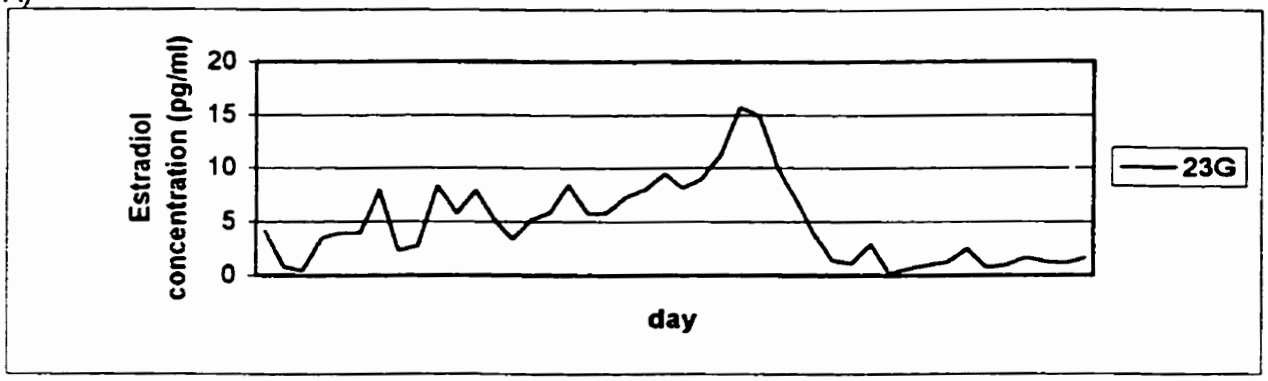
Figure A13. Sow 607F. Trt: p.m. / Parity: 4 / Trial: 1

Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus

standing estrus

A)



B)

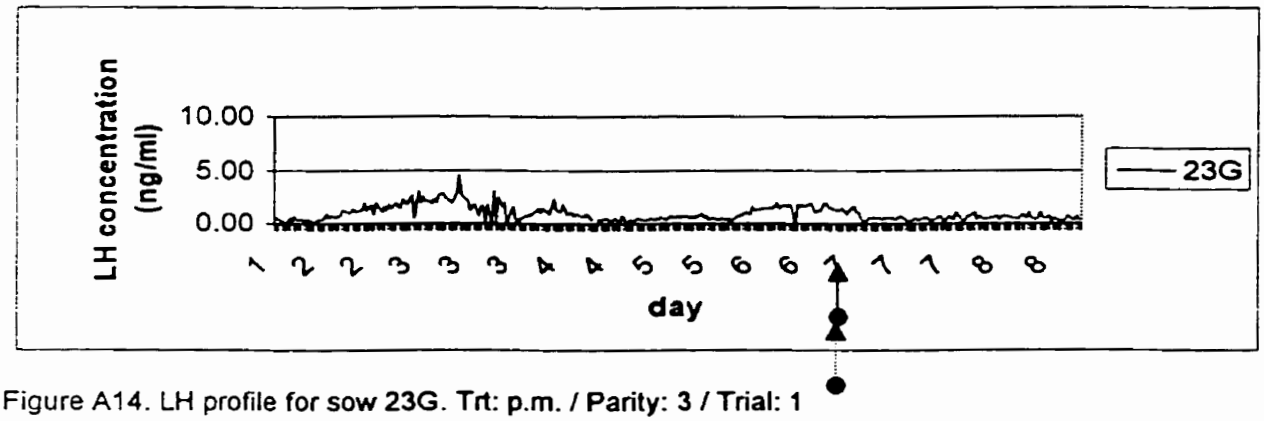
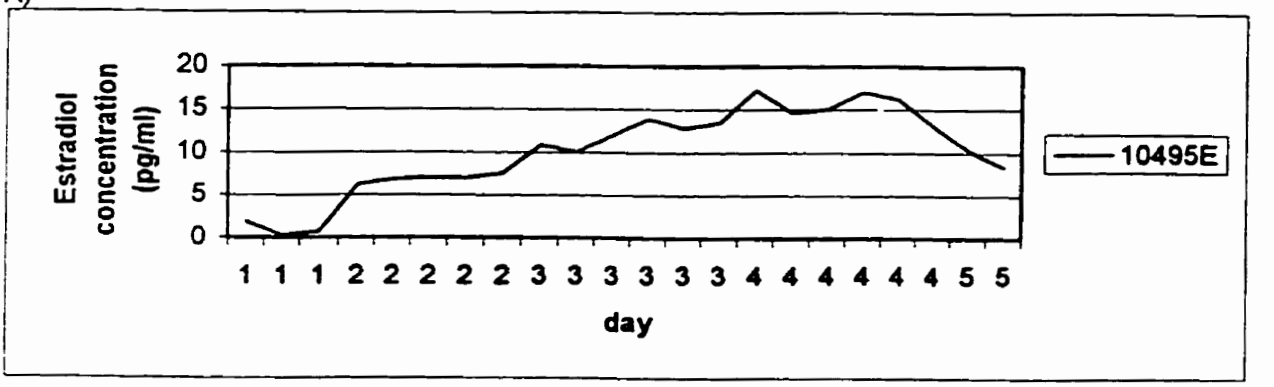


Figure A14. LH profile for sow 23G. Trt: p.m. / Parity: 3 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

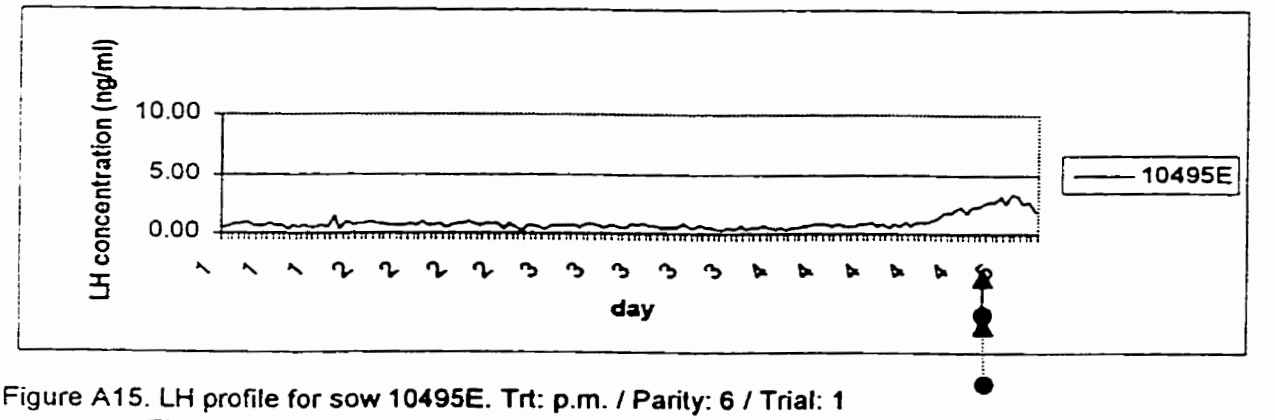
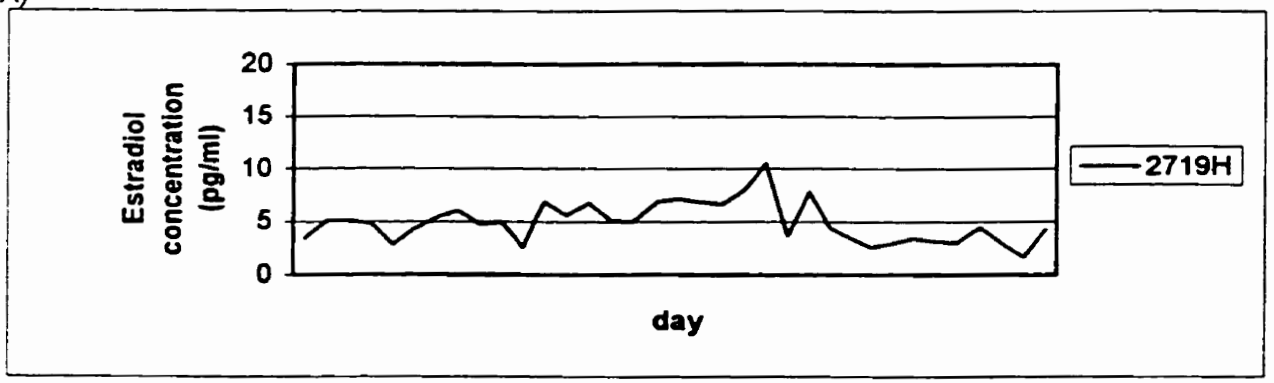


Figure A15. LH profile for sow 10495E. Trt: p.m. / Parity: 6 / Trial: 1
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

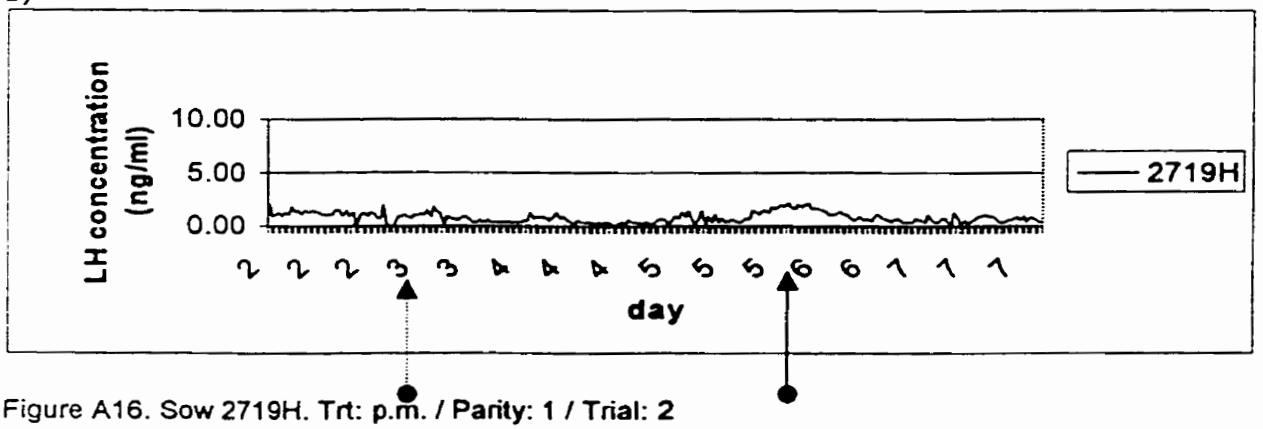
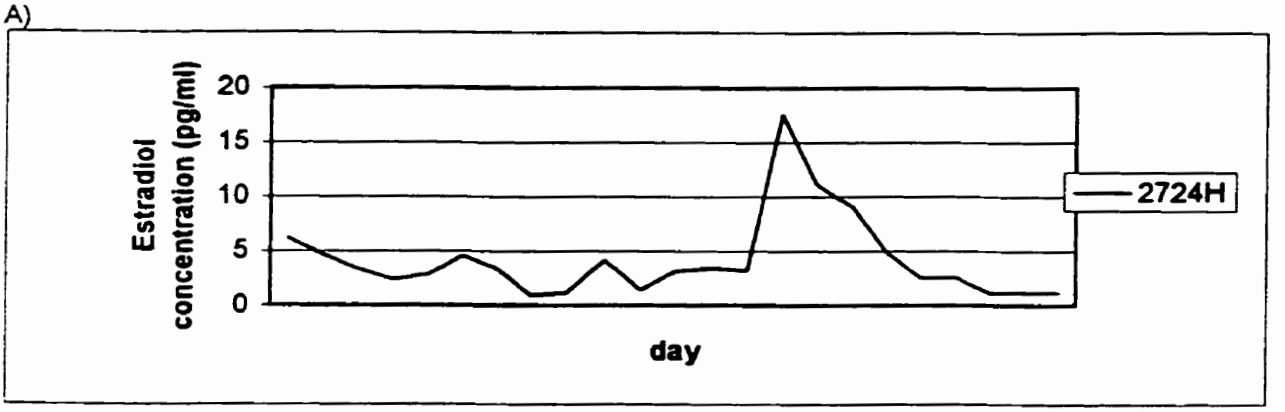


Figure A16. Sow 2719H. Trt: p.m. / Parity: 1 / Trial: 2
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

A)



B)

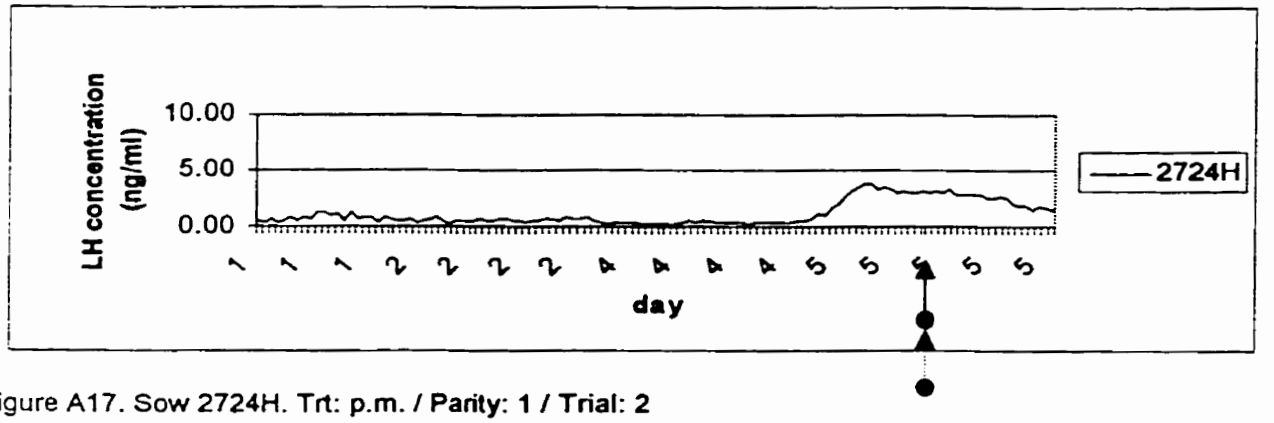


Figure A17. Sow 2724H. Trt: p.m. / Parity: 1 / Trial: 2
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus

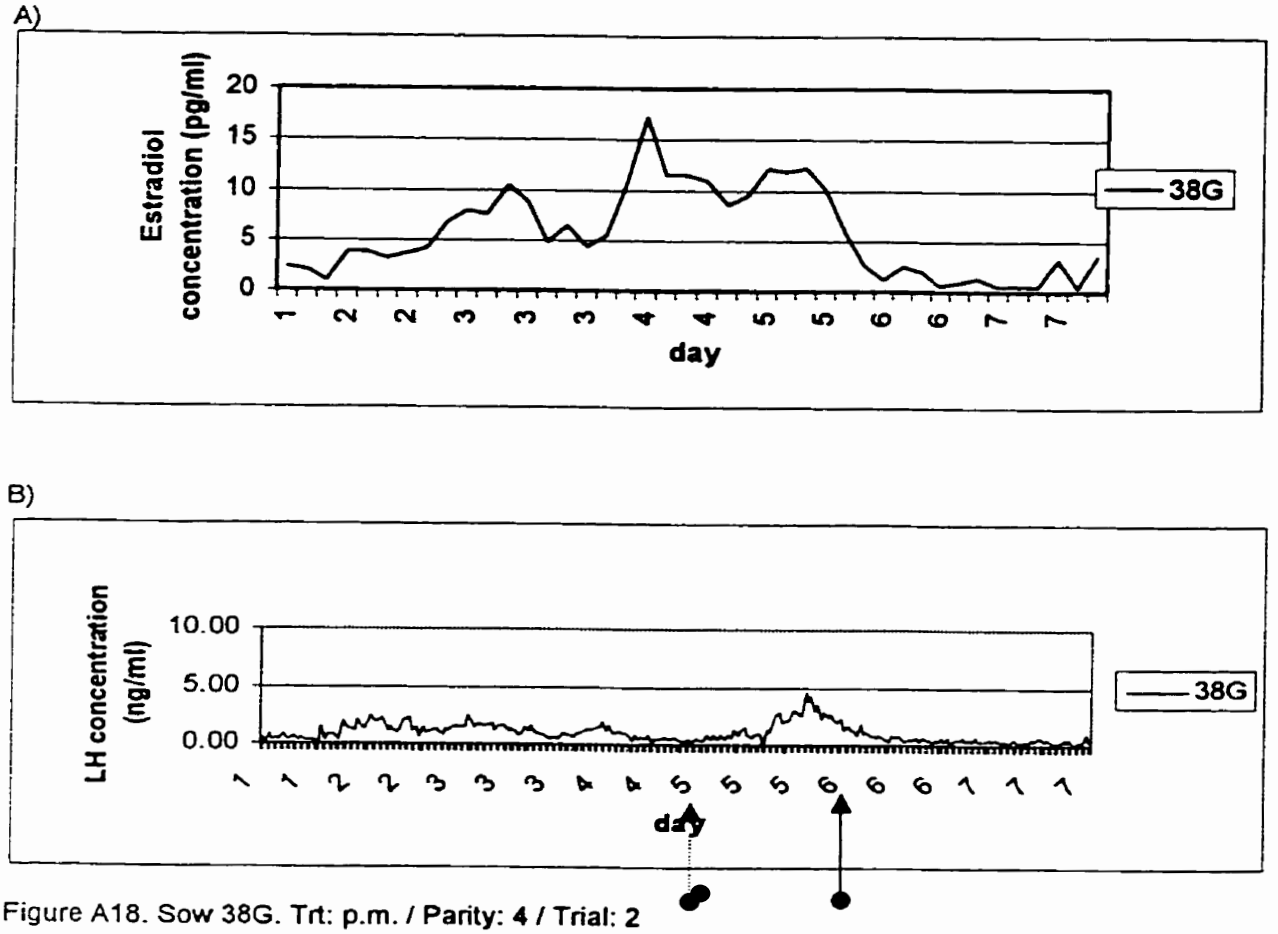


Figure A18. Sow 38G. Trt: p.m. / Parity: 4 / Trial: 2
Figure (A) indicates E2 profile over time. Figure (B) indicates LH profile over time.

signs of estrus
standing estrus