ESTRUS INDUCTION AND MAINTENANCE OF CYCLES IN GILTS WITH PG-600 AND BOAR EXPOSURE

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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and hereby certify that, in their opinion, it is worthy of acceptance.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ESTRUS INDUCTION AND MAINTENANCE OF CYCLES IN GILTS WITH PG-600 AND BOAR EXPOSURE

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ABSTRACT

The ability to induce puberty in gilts at an earlier and predictable age can facilitate introduction into the breeding herd. One method to initiate puberty (PG-600; 400 IU of PMSG and 200 IU of hCG, Intervet, Millsboro, DE), elicits estrus in a majority of gilts. However, a proportion of those gilts do not recycle normally. This study looked at the efficacy of PG-600 and boar exposure, alone and in combination, to induce and maintain regular cycles. Two replicates of 160 gilts each (182 days old) were conducted on a commercial farm in June and July, 2006. Replicates were combined for analysis. Gilts were presumed prepubertal on arrival from the multiplier and randomly assigned to one of four treatments in a 2 x 2 factorial arrangement: PG-600, weekday 10 min of full physical contact boar exposure (BE), PG-600 + BE, and neither PG-600 nor BE (control). Initial weight and backfat measurements were taken. Detection of estrus was performed during BE or during two min of fence-line boar exposure. Gilts were considered in estrus when they stood to be mounted. A total of six gilts were removed from the experiment for health reasons. The PG-600 and PG-600 + BE gilts had a higher ($P < 0.0001$) percentage in estrus within seven days than the BE and control treatments (69.4 ± 7.04 %, 80.8 ± 7.04 % versus 25.1 ± 7.04 %, 12.5 ± 7.04 %, respectively). Eighty-five of 146 gilts in estrus within seven days returned to estrus 18 to 23 days later. Although the BE and control groups had fewer gilts respond within seven days, a larger proportion recycled within 18 to 23 days; (100 ± 9.74 % of BE versus 78 ± 9.74 % control and, 55.8 ± 9.11 % and 50 ± 9.11 % for PG-600 and PG-600 + BE respectively). Half of control gilts showed estrus within 30 days regardless of initial weight. PG-600 and BE gilts with heavier initial weights had a higher probability of coming into estrus. Heavier gilts in the PG-600 + BE group had a lower probability of cycling. Similar probabilities were seen for initial age. Gilts that expressed estrus within 30 days in all treatment groups did so regardless of back-fat thickness. There was no significant difference among treatments regarding first farrowing rate and litter size. The greatest response was to PG-600. Response to BE is dependent on many factors, and in this study was lower than expected. Addition of daily boar exposure to PG-600 did not result in dramatic increase in proportion maintaining cycles and may not be warranted.

CHAPTER I

INTRODUCTION

Gilts comprise a large proportion of the breeding herd, so the ability to induce puberty in gilts at an earlier and predictable age to facilitate introduction into the breeding herd and reduce the non-productive days (days when female is neither pregnant nor lactating) is important in maximizing herd efficiency. Puberty in gilts is defined as the first estrous period and naturally occurs at the age which the reproductive organs become functionally operative (Hughes and Varley, 1980). The expression of estrus, or standing heat, is normally associated with ovulation. Age at puberty can be influenced by manipulating genetic and environmental factors. Although reproductive traits are not highly heritable, they do respond to crossbreeding, inbreeding and selection. Environmental factors such as season, photoperiod, temperature, and air quality can influence the onset of puberty, as can management practices such as relocation or mixing of gilts. The presence of a mature boar is the most effective factor in puberty induction. However, boar exposure is often underused due to labor and time constraints, so the use of gonadotrophic hormones, such as PG-600 (Intervet, Millsboro, DE), is a popular alternative to boar exposure. Problems have been reported with the predictability of gilts maintaining a normal cycle after a PG-600-induced estrus. The addition of boar exposure has been found to partly remedy this problem by enhancing the maintenance of cyclic activity and the expression of estrus. The purpose of the present study was to evaluate the efficacy of PG-600 and boar exposure, alone and in combination, on estrus induction and maintenance of cycles in a commercial setting.

CHAPTER II

LITERATURE REVIEW

Genetics

The genetic background of the gilt plays an important role in the onset of puberty. When reared on pasture and fed a high protein diet, Poland China gilts attained puberty significantly earlier than similarly reared Chester White gilts (Robertson et al., 1951a). In another experiment by Robertson et al. (1951b) no significant difference in age at puberty between Poland China and Chester White gilts was seen. There was, however, a significant difference in weight at first estrus, with Poland China gilts averaging 5.45 kg heavier than Chester White gilts. Within each breed, age at first estrus was more constant than weight at first estrus, suggesting that age is a better measure than weight for gilt maturity. In an experiment by Self et al. (1955), Chester White gilts attained puberty at 225 days of age, and this differed significantly from the mean age at puberty for Poland China gilts (206 days of age). A second trial using gilts of similar age found no breed difference.

There are three types of Poland China: small, medium and large. Phillips and Zeller (1943) evaluated the small and large types and found no significant difference in age or weight at puberty between the two. However, there was a tendency for a more rapid development in the large type, and based on prior breeding experience, the small type often had more difficulty in maintaining regular cyclic activity. A negative correlation between weight and age at puberty was reported between types.

Foote et al. (1956) reported the effect of mating systems on age at puberty. The mean age at puberty for inbred Chester White and Yorkshire gilts was 227.7 days, which was significantly older than line-cross Chester White x Yorkshire gilts (193.4 days of age). A significant difference between purebred and crossbred gilts was also reported. Purebred Yorkshire, Poland China and Duroc gilts attained puberty at a significantly older age (285.1 days) compared to the crossbred Yorkshire x Poland, Yorkshire x Duroc, Poland x Duroc, (221.7 days). Zimmerman et al. (1960) reported that Chester White x Poland China crossbred gilts attained puberty significantly earlier than the purebred gilts (182.3 vs. 204.0 days of age, respectively). The effect of season of birth on age at puberty differed for the two breeds. Gilts born in the spring attained puberty 12.2 days earlier than fall-born gilts in the Chester White breed, while the fall-born Poland China gilts attained puberty 13.3 days earlier than spring-born Poland China gilts. Clark et al. (1970) reported differences in age at puberty in two lines of gilts and their crosses (226, 247, 231 and 213 days for Poland China, Yorkshire, Yorkshire X Poland China and Poland China X Yorkshire, respectively). Two experiments found significant differences in age at puberty between inbred gilt lines (Warnick et al., 1949 and Warnick et al., 1951).

All of the above experiments used gilts reared on dry lots or pasture. Work has been done to evaluate breed and mating system effects on gilts reared in confinement. Christenson and Ford (1979) investigated age at puberty and maintenance of regular estrous cycles in gilts of five breeds (Duroc, Hampshire, Large White, Swedish Landrace and Yorkshire) reared in confinement. The proportion of Swedish Landrace gilts showing regular estrous cycles at six months of age was higher than that of Hampshire, Large White, Yorkshire and Duroc gilts (69 vs. 11, 4, 3, and 0 % respectively). By eight and one-half months of age, the estrous activity of all gilts had reached a plateau. By nine months of age the proportion of gilts showing regular estrous cycles was greater for Large White, Swedish Landrace, Hampshire and Duroc gilts than for Yorkshire gilts (86, 78, 71, 71, vs. 56 %, respectively). Beyond nine months of age, the proportion of gilts showing regular activity did not significantly increase, suggesting that retention of non-cyclic gilts beyond nine months of age for replacement would not be productive.

A similar experiment evaluated crossbred and purebred gilts either reared in confinement or in dry lots (Christenson, 1981). Percentage of cyclic gilts by nine months of age was highest among Swedish Landrace x Large White crossbred gilts (96.5 %) and the lowest was the purebred Hampshire, Yorkshire and Duroc gilts (81.3, 71.1 and 60.3 %, respectively). An influence of housing was also reported. Fewer gilts reared in confinement were cyclic by nine months of age than non-confined gilts (71.3 vs. 85.2 %). At seven and nine months of age, estrous activity was lower in confinement-reared Duroc and Yorkshire gilts than in confinement-reared Swedish Landrace x Large White and Hampshire gilts (Christenson, 1981). Cronin et al. (1983) reported an effect of breed and crossbreeding on confinement-reared gilts. Significantly more Large White gilts and Large White x Landrace gilts attained puberty by 245 days of age than did Landrace gilts. More crossbred gilts attained puberty by 245 days of age than purebred gilts.

Hughes and Cole (1975) reported sire effects on the attainment of puberty in a pool of gilts from four Landrace boars. Age and weight at puberty differed significantly according to sire. Signoret et al. (1990) also reported a sire effect on crossbred gilts (51 vs. 73.5 % in estrus within seven days for sire A and sire B, respectively). Evaluation of

Chester White and Poland China gilts showed no significant differences in ages at puberty between gilts of different sires (Zimmerman et al., 1960). Differences in weight at puberty between gilts of different sires were significant in the Chester Whites but not in the Poland China (Zimmerman et al., 1960). Breed differences in the response of gilts to the back-pressure test was reported by Cronin et al. (1983).

Tilton et al. (1995) reported that gilts from two genetic lines responded differently to gonadotrophin treatments (PG-600, Intervet, Millsboro, DE) used to induce pubertal estrus. Gilts from the line selected to reach puberty at a younger age responded more favorably to gonadotrophin treatment than gilts under relaxed selection. Zimmerman et al. (2000) also reported a quicker response to boar exposure in a genetic line of gilts selected for early puberty compared to gilts selected for increased ovulation rate and litter size.

Traits associated with reproductive efficiency are lowly heritable. Improvements can be made in these traits by using mating systems that take advantage of hybrid vigor. This is done by crossbreeding with breeds or lines of swine not closely related. The result is offspring expressing an improvement in traits compared to the average of the sire and dam breeds (Foote et al., 1956; Zimmerman et al., 1960). It is important to note that the heritability of age at puberty is actually relatively high (0.35; Clutter and Schinckel, 2001), so replacement gilts should not be retained from dams that were older at first estrus or in conceiving their first litter (Christenson and Ford, 1979). For moderate to highly heritable traits, such as growth rate (0.30), feed efficiency (0.35) and backfat (0.50), selection upon individual performance allows for a relatively rapid rate of improvement (Cleveland et al., 1998). However, selection for particular traits should be done cautiously because other traits may be inadvertently selected against.

Gaughan et al. (1997) allotted gilts into groups by backfat thickness at 140 days of age: low (10 to 12 mm), medium (13 to 15 mm) or high (16 to 18 mm). By 202 days of age the proportion of gilts attaining puberty was 100 % for high, 92 % for medium and 67 % for low. Of the gilts that attained puberty by 202 days of age, the number of estrous cycles from 145 to 202 days of age was 2.25 for high, 1.96 for medium and 1.16 for low. The number of follicles at 202 days of age was 18.25 for high, 19.08 for medium and 13.14 for low. Gilts with a higher protein deposition rate attained puberty in a greater proportion. Therefore, the rate of fat and protein deposition appears to be one of the determinants of puberty attainment. Eliasson et al. (1991) reported the growth rate (25 to 90 kg live-weight) was negatively correlated with age at puberty, and gilts with low backfat thickness at 90 kg live-weight attained puberty later than gilts with high backfat thickness at 90 kg. Negative correlations between age at puberty and growth rate have been also been reported by Hutchens et al. (1981) and Rydhmer et al. (1994).

Experiments conducted by Rydhmer et al. (1992) and Beltranena et al. (1993) suggest high lean growth rates may delay the onset of puberty. Rydhmer et al. 1994 reported a negative correlation between percentage of lean and intensity of reddening and swelling of vulva. A negative correlation between growth rate and length of standing estrus was also reported, with gilts with a high capacity for growth having a lower capacity for showing standing estrus than gilts with a lower growth rate.

In contrast, Cameron et al. (1999) suggested that selection for lean growth rate had no adverse effects on sexual development, and that it is selection for lean feed conversion that leads to problems in sexual maturity. However, there are benefits for having fat on gilts. In an experiment by Gaughan et al. (1997), the gilts with higher fat and protein deposition attained puberty the earliest, and Eliasson et al. (1991), reported a negative correlation between age at puberty and backfat thickness at 90 kg body weight. Regardless of which traits are the more important determinants of puberty attainment, it is critical to have a good estrus detection procedure as expression of estrus can be altered.

The expression of any trait depends on both the genetic background of the gilt and its environment. It is important to consider genetics for relations between production and reproduction traits. The balance between fat and lean tissue is important, so care should be taken to avoid selection of extreme gilts. Therefore, good reproductive management involves selecting gilts that perform well under a particular farm situation and takes into consideration factors modified by the environment, such as season and housing.

Nutrition

Plane of nutrition, feed intake and the composition of the diet influences puberty attainment in the gilt. Restricted feeding has been shown to alter age at puberty. The effect obtained, however, has been variable. Robertson et al. (1951a) found that puberty was delayed by limited feeding, and Zimmerman et al. (1960) reported that Chester White and Poland China gilts fed ad libitum grew more rapidly and attained puberty at an earlier age than limited-fed gilts. A breed effect was also reported, with the Poland China gilts being heavier than the Chester White gilts in four of five trials. Beltranena et al. (1991) reported that feed restriction delayed puberty in crossbred (Yorkshire x Landrace) gilts. Ogle and Dalin (1989) reported data on a 2 x 2 factorial, with two initial live weights (light (L) or heavy (H)) and either a low (lp) or high (hp) plane of feeding during the rearing period. When feed intake was restricted, puberty was delayed an average of 17 days. The Hhp gilts reached puberty 26.4 days earlier than the Hlp gilts. The hp gilts were significantly heavier and had thicker backfat than the lp gilts at first estrus.

Lodge and MacPherson (1961) reported age at puberty for gilts fed a high plane diet was not significantly different from gilts fed a low plane diet.

In contrast, Self et al. (1955) reported age at puberty for gilts fed a high plane diet were significantly older at puberty than the low plane gilts (223 vs. 208 days, respectively). Stalder et al. (1998) found an increased probability of gilt farrowing rate in gilts fed restricted quantities of a high energy-high protein diet from 82 kg live weight to 180 days of age as compared to gilts with ad libitum access to either the high-energy-high protein diet or a high energy-low protein diet.

Other studies have demonstrated the effect of nutrition on hormonal function. In prepubertal gilts, feed restriction to 50 % of ad libitum intake clearly reduced luteinizing hormone (LH) pulse frequency in long term (Prunier et al. 1993) and short-term experiments (Cosgrove et al., 1993). The reduced hormonal activity retarded growth and sexual development. Seren et al. (1990) and Booth et al. (1994) reported an increased feed intake of restrictively fed prepubertal gilts enhanced LH activity, increased uterine weight and advanced follicular activity.

Eliasson et al. (1991) reported gilts fed a high-protein diet (18.5 % CP, 0.96 % lysine) attained puberty at a younger age than gilts fed a low-protein diet (13.1 CP, 0.64 % lysine). High protein intake enhances steroid metabolism, thereby reducing circulating estradiol and removing the negative feedback on the release of LH. A negative correlation was reported between growth rate and age at puberty for gilts fed a high-protein diet.

Robertson et al. (1951b) found high protein intake retarded the onset of puberty. Gilts were fed diets of varying CP content (20, 15, and 11.25 %) from weaning to 56.7 kg live weight. Gilts on the low-protein diet were six days younger at puberty. In contrast, Cunningham et al. (1974) reported that gilts fed 14 % CP attained puberty 18.7 days earlier than gilts fed 10 % CP. In a more recent experiment, Stalder et al. (2000) evaluated gilt reproductive performance on three different high-energy development diets. Diets varied in CP content: Diet 1, 18 % CP; Diet 2, 13 %; Diet 3, 23 % CP. No significant differences were seen among diets. Gilts were from five lines selected to represent a broad range of variation in lean growth and reproduction.

Friend (1973) observed that gilts fed diets supplemented with lysine and methionine attained puberty 12 and 24 days earlier than controls. Witz and Beeson (1951) suggested that puberty may be delayed and ovarian growth retarded in gilts reared on a fat-free diet.

Klindt et al. (1999) subjected gilts to three feeding regimes with a feed formulated to primarily restrict energy intake: Ad lib, (ad libitum access to feed from 13 to 25 weeks of age); Control, (ad libitum access to feed from 13 weeks of age until 100 kg, then restricted to 90 % of the amount of feed consumed by the Ad lib group until 25 week of age); Restricted, (74 % of the amount of feed consumed by the Ad lib group from 13 to 25 weeks of age). Gilts were mated at first estrus and gilts that recycled were mated again. The age at puberty (196 days) and reproductive performance through 30 days of pregnancy were similar among treatments. A similar experiment by Klindt et al. (2001), reported no difference among treatments on age at puberty and reproductive performance from 13 weeks of age to the end of pregnancy. Therefore, a moderate feed restriction may be implemented to reduce feed cost without any negative impact on reproductive performance from 13 weeks of age through the entirety of the first pregnancy. Gilts used in both experiments were crossbred (American Landrace x Yorkshire) gilts. Patterson et al. (2002a) also suggested a moderate restriction, reporting that gilts responding to boar exposure at an older age had a higher feed consumption than the quicker responding gilts.

Gosset and Sorenson (1959) fed gilts two diets of different energy levels ad libitum and reported the limited-energy (55 therms per 45.35 kg) gilts attained puberty at a similar age as the high-energy (93 therms per 45.35 kg) gilts. Ovulation rates were similar as well, but interestingly, the lower energy gilts had a significantly greater number of embryos present at 40 days of pregnancy. Zimmerman et al. (1960) reported that feeding high levels of energy for periods as short as 10 to 14 days prior to estrus (flushing) increased ovulation rates in gilts over gilts fed basal diets. Similar results were reported by Sorenson et al. (1961). However, as was seen in Gosset and Sorenson (1959), when gilts continue to consume a high-energy diet or are fed ad libitum post-mating, decreased embryo survival will be observed (den Hartog and van Kempen, 1980).

It is important not to stray far from the nutritional recommendations published by the National Research Council (NRC). However, feeding in excess can be wasteful and costly. A moderate feed restriction using balanced, fortified diets will help develop sexually mature gilts. Flushing 10 to 14 days prior to estrus will maximize ovulation rates, but should be discontinued immediately after first mating to prevent embryonic mortality (Rhodes et al., 1991; Davis et al., 1987).

Boar Effect

The most successful method in inducing pubertal estrus in gilts is the use of mature boars. The age of gilts at first boar exposure is an important factor influencing the degree of response to stimulate and synchronize pubertal estrus. Zimmerman et al. (1969) allotted gilts (15 breed composite) into heavy and light weight groups and exposed them to 30 minutes of daily boar exposure at 103 or 126 days of age. Control gilts received no boar exposure. The older gilts matured earlier with boar exposure than the younger gilts (148.1 vs. 160.5 days, respectively), and both boar-exposed groups responded earlier than the controls (182.6 days). The heavy gilts were younger at puberty compared to the light gilts in their respective weight groups (Zimmerman et al., 1969).

Hughes and Cole (1976) fed gilts to reach 73 kg by 135, 160 or 190 days of age. Boar exposure was initiated at the respective ages. The 190-day old group was oldest at puberty (205.3 days), but the interval to estrus was longer in the 135-day group. Bourn et al. (1974) found exposure at 135 days of age led to an earlier puberty (156 days of age) than exposure at 165 days (173 days of age). But like Zimmerman et al. (1969), and Hughes and Cole (1976), the interval to puberty was longer for the younger group. Cronin (1983) reported that a difference in age by a few weeks (23 and 28 weeks of age) was enough to see a significant difference in reproductive efficiency in Large White, Landrace, and crossbred prepubertal gilts. Gilts exposed to a mature boar at 23 weeks of age tended to be more sexually receptive to the boar. A significantly higher mating rate was seen in the 23 week-old gilts than in the 28 week-old gilts (70.1 vs. 66.0 %). The number of prepubertal gilts at 35 weeks of age was significantly lower for the 23 week-old group (1.46 vs. 3.03 %). Hemsworth et al. (1982) found that gilts reared in isolation from boars until 180 days of age had a lower mating rate than gilts exposed earlier. This was due to reduced sexual receptivity and estrus expression. Two similar experiments agreed that delaying the application of boar exposure beyond 160 days of age resulted in gilts being significantly older and heavier at puberty (Kirkwood and Hughes, 1979; Eastham et al., 1986).

Zimmerman et al. (2000) conducted an experiment to evaluate the response to boar exposure in gilts of different genetic lines and age. Gilts were either from a line selected for early age at puberty (AP) or a composite of genetic lines selected for ovulation rate and litter size (RLS). Boar exposure was initiated in AP gilts at 130 days of age and at 130 or 154 days of age for the RLS gilts. AP gilts showed a more rapid and synchronous response to puberty than the RLS gilts. This was expected because 130 days is near the natural onset of puberty for this gilt line. RLS gilts first exposed to boars at 130 days attained puberty earlier (168.0 days) than RLS gilts exposed at 154 days of age (175.4 days of age), but the interval to puberty was shorter in the 154 day-old gilts (21.8 vs. 35.2 days for 154 and 130 days of age, respectively). This experiment demonstrated that the initiation of boar exposure was most effective at inducing a rapid and synchronous response to first estrus when gilts were nearing puberty (130 days for AP gilts and 154 days for RLS gilts). Overall, initiating boar exposure too early or too late leads to a less synchronous response and at times, delayed puberty. Initiating boar exposure around two or three weeks before the anticipated age at puberty will get a larger proportion of gilts cycling and in a more synchronous manner. Gilts will differ in their natural pubertal age due to differences in breed, composite or mating system (Robertson et al., 1951a; Zimmerman et al., 2000; Foote et al., 1956).

Kirkwood and Hughes (1980a) reported data on an experiment that showed no effect of boar exposure or relocation on gilt age at puberty. Gilts either received 30 minutes of daily boar exposure, or were relocated to a new pen, or were relocated and exposed to Boar-Mate (Antec-International, Sudbury, Suffolk). Boar-Mate is a commercially available aerosol containing 5α-androstenone, a pheromone found in boar saliva. It was applied directly to the nostrils of the gilts and on their feed. A fourth group received no stimulus (control). The lack of response in this study was not in agreement with earlier reports that demonstrated the advantage of boar stimulation over no boar stimulation (Zimmerman et al., 1969; Hughes and Cole 1976; Kirkwood and Hughes 1979). The boar exposure provided by Kirkwood and Hughes (1980a) was with a six-month old boar. It was suggested that young boars (≤ 6 months of age) produce inadequate levels of pheromones in their saliva or urine. Kirkwood and Hughes (1981) conducted a study comparing the effectiveness of 30 minutes of daily boar exposure with boars of 2 years, 11 months or 6.5 months of age. Gilts were 165 days of age and a control group received no boar exposure. Gilts exposed to the 2-year and 11-month old boars attained puberty significantly earlier (182 and 181.6 days) than gilts receiving exposure from the 6.5-month old boar or the controls (206 and 203 days, respectively). Kirkwood et al. (1981), provided evidence that the primary boar stimulus is olfactory in nature and involves 16-androstene pheromones produced by the submaxillary glands and secreted in saliva. Therefore, it was speculated that the submaxillary glands of young boars (≤ 6.5 months of age) were too immature to produce adequate levels of 16-androstene pheromones (Kirkwood and Hughes, 1981).

Two experiments by Kinsey et al. (1976) investigated gilt response to individual components of boar exposure. The first experiment assigned confinement-reared gilts to receive five to 10 minutes of recorded boar chant or recorded boar chant and fence-line exposure to a barrow on a daily basis. A third group was un-stimulated controls. The second experiment assigned pasture-reared gilts to five to 10 minutes of recorded boar chant; a boar urine odor box; a combination of boar chant and odor box; physical boar exposure; and physical exposure to a barrow on a daily basis. None of the treatments stimulated an early response to puberty, and puberty was actually delayed in gilts exposed to boar urine, alone or with boar chant. No explanation was given for gilt response.

Hemsworth et al. (1982) conducted two experiments evaluating gilt response to varying degrees of boar contact. When gilts were reared in the presence of a boar from four or five weeks of age until the initiation of estrus detection and mating (26 or 27 weeks of age), the mating rate significantly increased compared to gilts isolated from boars for the entire period. The second experiment penned gilts one to two meters from a mature boar and gave them 10 minutes of physical boar contact or no contact. The mating rates were similar between the groups.

An experiment by Kirkwood et al. (1981) assigned gilts to four treatments: gilts had their olfactory bulbs removed and given daily boar exposure; gilts had a sham surgery performed and given daily boar exposure; intact gilts given daily boar exposure; and intact gilts isolated from boars. Age at puberty was similar for the sham and intact boar-exposed gilts and significantly younger than boar-exposed bulbectomized gilts and intact controls (204 and 208 vs. 230 and 234 days of age, respectively). These reports implicate olfactory cues as a necessary component in boar exposure.

Kinsey et al. (1976) demonstrated delayed puberty in gilts exposed to boar urine, and Stephens and Close (1984) and Kirkwood and Hughes (1980a) demonstrated no primer effect when Boar-Mate was sprayed on the nose or applied to feed, further suggesting that the olfactory stimulus is provided by 16-androstene pheromones.

In an experiment conducted by Pearce et al. (1988), gilts received daily boar exposure from mature boars with either intact boars, sialectomized boars (submaxillary glands removed) or boars that had sham surgery. Control gilts were isolated from boars. Gilts receiving exposure from intact boars were the youngest at puberty (179 days of age), followed by exposure to the sialectomized and sham boars (203.5 and 202.0 days of age, respectively). Control gilts were the oldest (227 days of age). Saliva from the boars was collected and analyzed for 3α –androstenol and 5α–androstenone. Salivation was induced by pilocarpine administration, aggressive encounters with other boars or mating. Levels of the steroids differed among stimulation methods and among boars. Champing and salivation are important in dissipating the pheromones (Perry et al., 1980). Pearce and Hughes (1987) reported that nose-to-nose contact between gilt and boar is important in the transference of pheromones. An experiment by Pearce and Paterson, (1992) assigned gilts of 160 days at age to three treatments: daily full boar exposure for 20 minutes with gilts wearing a snout mask; 20 minutes of daily full boar exposure (unrestrictive); and isolated from boars (control). The boar-exposed gilts attained puberty significantly earlier than the control gilts. The mean interval to puberty for unrestrictive full-contact gilts was significantly shorter than masked gilts (9.1 vs. 17.4 days, respectively).

The reported data suggests that stimuli of the olfactory system (16-androstene pheromones) from the boar and the simultaneous physical contact (full or fence-line) are required to induce puberty in gilts. Visual and auditory cues likely add to the effect.

From 70 to 154 days of age, Cole et al. (1982), reared gilts with either contemporary gilts, boars or barrows. At 154 days of age, gilts were relocated to outdoor lots adjacent to a mature boar and exposed to thirty minutes of daily full physical boar exposure at 160 days. The gilts reared with contemporary boars or barrows were younger at puberty than gilts reared with other gilts, and the intervals from mature boar exposure at 160 days of age to puberty were 7.4, 7.1 and 8.9 days for boars, barrows and gilts, respectively. Although the difference was small, it was significant. A similar study by Nathan and Cole (1981) reported no significant difference in age at puberty for gilts reared with boars, barrows or gilts. However, Paterson and Lindsay (1980), reported that gilts reared with contemporary boars and provided no mature boar exposure were younger at puberty than those reared with barrows.

Pearce and Hughes (1985) reported gilts were insufficiently stimulated when moved to a different pen on a daily basis compared to gilts receiving boar exposure. Karlbom (1982) evaluated whether providing continuous fence-line boar exposure led to habituation to the boar. Gilts were reared with continuous fence-line boar exposure from 84 days of age until puberty. From 142 days of age, half of the gilts were provided an additional 20 minutes of daily full physical boar contact. A third group of gilts remained isolated from boars. Boar-exposed gilts attained puberty earlier than the controls, and gilts that were provided additional full contact attained puberty 20 days earlier than those receiving fence-line only. Pearce and Paterson (1992) also reported a higher response to daily full contact compared to fence-line alone. Deligeorgis et al. (1984), exposed gilts to different degrees of boar contact. At 156 days of age, gilts were either exposed to 20 hours of full physical boar contact or 20 hours of fence-line contact. Control gilts were penned away from boars. A larger proportion of gilts receiving full contact expressed estrus than fence-line and control gilts (76, 38, and 19 %) and attained puberty at an earlier age (167.9, 192.2 and 191.2, respectively). The response of fence-line gilts was expected to be quicker than control gilts (Karlbom 1982; Pearce and Paterson, 1992), but this was not the case in this experiment. An explanation for this may be due to the fact that the boars providing full contact were simultaneously providing the fence-line exposure, so the boars may not have spent an adequate amount of time at the fence.

Brooks and Cole (1970) suggested that exposure to the same boar may cause habituation. So, Brooks and Cole (1970) allotted gilts into two groups to receive 30 minutes of boar exposure per day at 165 days of age. One group received exposure from one boar, and the other group received exposure from a pair of litter brothers on a rotating basis. The gilts exposed to the pair responded earlier and in a more synchronous manner than the one-boar group. Siswadi and Hughes (1995) reported when gilts were taken to a boar house (high stimulation environment), a higher proportion of gilts expressed estrus by 220 days of age when given physical boar contact compared to fence-line contact (79 vs. 41 %). Scheimann et al. (1976), reported that a higher proportion of gilts attained puberty when they were taken to boar pens for boar exposure and estrus detection compared to taking boars to gilt pens (78 vs. 46 %, respectively). Van Lunen and Aherne (1987) reported similar results, with 68 % of gilts taken to boar pens responding and 48 % responding when the boar was brought to the gilts. Patterson et al. (2002a) reported that full physical contact with a mature boar, whether taking the boar to the gilt or the gilt to the boar, reduced the interval to puberty in both groups, compared to gilts receiving fence-line contact. No significant differences existed between the two methods of full contact. Thompson and Savage (1978) penned gilts adjacent to a mature boar at 6.5 months of age for 30 days. Control groups were isolated from boars for the 30 days. At seven months of age, gilts were moved outdoors and checked daily with a boar for estrus. The gilts penned adjacent to a mature boar in confinement attained puberty significantly younger than the controls.

Hughes (1994) performed two experiments to evaluate the effect of frequency and duration of boar contact on gilt response. In the first experiment, gilts were exposed to a mature boar on either alternate days (ADB), daily (DB), twice daily (2DB), or no boar exposure (control) at 160 days of age. Each exposure period was 20 minutes. The boar exposure groups attained puberty in significantly larger proportions than the control group. There was a significantly higher proportion of 2DB gilts reaching puberty within the first 20 days of treatment than for DB and ADB (86 vs. 21 and 7 %, respectively). The second experiment exposed gilts to a mature boar daily (D), twice daily (2D), three times daily (3D), or no boar exposure (control) at 160 days of age. Each exposure period of boar contact lasted for 60 minutes for D, 30 minutes for 2D, and 20 minutes for 3D. All boar exposure groups experienced a significant increase in the proportion of gilts attaining puberty compared with control gilts. There was a significantly higher proportion of 3D gilts reaching puberty within 20 days than 2D and D (62 vs. 27 and 25

%, respectively). Paterson et al. (1989b) exposed gilts to 30 minutes of full physical boar contact from 175 days of age for: 0 days per week (control); two (2) days per week; five (5) days per week or seven (7) days per week until puberty or 235 days of age. Three replicates were conducted during the spring, summer and fall months. The frequency of boar exposure did not affect the proportion of gilts attaining puberty. But, the interval to puberty was significantly shorter for 7 and 5 day exposure groups compared to the 2 day exposure group during the spring (16.5 and 18.4 vs. 32.3 days, respectively). The interval to puberty was significantly shorter for the 7 day exposure group compared to the 5 and 2 day exposure groups during the fall (11.4 vs. 33.8 and 32.6 days, respectively). The results further suggest that boar exposure is an additive stimulus.

Zimmerman et al. (1998) reported a tendency for once-daily exposure to decrease pubertal age over twice-daily when each boar exposure period was 10 minutes in duration. Philip and Hughes (1995) reported that by day 20 of boar exposure, the proportion of gilts cycling was only significantly different between three daily boar exposures (20 minutes per period) and once-daily exposure for 60 minutes; three exposure periods was not significantly different from two exposure periods. Hughes et al. (1997) demonstrated the combination of frequent boar exposure and transport resulted in a quicker response than frequent boar exposure alone (24.7 vs. 37.4 days, respectively).

Kirkwood and Hughes (1980b) reported that 30 minutes of daily boar exposure was just as effective at inducing an early puberty as continuous boar exposure. Paterson et al. (1989a), exposed gilts to daily full boar exposure for 30 minutes, 10 minutes, two minutes or no exposure. The mean interval to puberty for non-exposed gilts was significantly longer (58.5 days) than for boar-exposed gilts (11.7, 7.4 and 24.9 days for 30, 10 and two minutes, respectively). Two minutes of boar exposure was not effective for a rapid response. When exposure is short, the boar does not have enough time to provide adequate stimulation to the gilts and therefore, the gilt does not receive the regular reinforcement required for a fast response. Ten minutes of daily full physical boar exposure was just as effective as housing gilts with a mature boar for four hours per day (Zimmerman et al., 1996). Hemsworth et al. (1988) reduced the duration of the boar exposure period to 5 minutes per day and found that puberty attainment was similar to that of gilts housed continuously with a vasectomized boar. Mavrogenis and Robison (1976) reported a seasonal effect on the efficacy of boar exposure. However, Caton et al. (1986), reported that increased frequency or duration of boar exposure may reduce the incidence of seasonal infertility.

Hughes (1993) reported effects of boar exposure duration, number of gilts per exposure group, and the size of the exposure pen on the efficacy of boar effect on gilts at 160 days of age. Duration of boar exposure was divided into three treatments: 20, 12.5 or five minutes of physical boar exposure per day. Gilts were in groups of eight, four or two, and the exposure pen was either large (22.2 m^2) or small (11.1 m^2). Twenty minutes of boar exposure significantly decreased the age at puberty and increased the proportion attaining puberty within 21 days compared to 12.5 and five minutes. An increase in group size and pen size decreased the interaction of boar and gilt, but did not significantly affect age at puberty or proportion cycling within 21 days.

Hughes (1994) allocated crossbred gilts to one of three treatments: daily boar exposure to a boar with high libido, daily boar exposure to a boar with low libido, and no boar exposure (control). Gilts in treatments receiving boar exposure reached puberty at a younger age than the control gilts. Gilts receiving exposure to the high libido boar reached puberty significantly earlier than did the low libido boar group (179.6 days vs. 194.1 days). Zimmerman et al. (1997) further looked to see if the effect of boar libido was influenced by gilt age. Gilts were either 140 or 160 days of age when the treatment was initiated. Ten minutes daily of boar exposure was initiated with either a high libido boar or low libido boar. The third treatment group was set as the control, receiving no boar exposure. Gilts from both groups receiving boar exposure reached puberty 21 days earlier than the control gilts. The high-libido group reached puberty 8.9 days earlier than the low-libido group. The younger gilts (140 days) reached puberty 11.3 days earlier than 160 day old gilts. The libido of the boar is an important boar-effect factor.

Hughes and Thorogood (1999) reported no significant difference in the pubertal response of gilts to a single period of boar exposure when it was provided in either the morning or the afternoon.

Boar exposure induces an early puberty in gilts reared in confinement (Kirkwood and Hughes, 1979) and non-confinement environments (Zimmerman et al., 1969). Full physical contact with the boar is superior in inducing puberty, however, fence-line contact can be very successful if nose-to-nose contact is made and the boar has enough time to interact with each gilt. The frequency and duration of boar exposure is important for successful and synchronous induction of estrus.

Seasonality

Season is a factor that influences puberty attainment in gilts. Several studies suggest that the season a gilt is born in has an influence on the age at puberty. Wiggins et al. (1950) reported that market weight gilts going to slaughter in late summer and fall were less sexually mature than at any other time of the year. The proportion of pubertal market gilts at slaughter was highest in April (85.4 %); gilts born during fall farrowing season); decreased sharply to 55.4 % in October (gilts born during the spring farrowing season), and increased to 81.2 % in January. Wiggins et al. (1950) also reported a larger proportion of gilts did not reach puberty by October slaughter when they were born between Feb 12 and April 2 (57 %) compared to gilts born between April 3 and May 20 (27 %), despite being older. Scanlon and Krishnamurthy (1974) evaluated the sexual maturity of market gilts throughout a 12 month period. The proportion of pubertal gilts was highest in February (34.5 %) and lowest in September (6.95 %). Similar findings on the effect of season of birth on age at puberty were reported by Robertson et al. (1951b), Zimmerman et al. (1960) and Mavrogenis and Robison, (1976). Two experiments investigating seasonal effects found no significant differences in age at puberty between fall and spring-farrowed gilts (Gosset and Sorenson, 1959; Sorenson et al., 1961). However, fall-farrowed gilts weighed significantly more than spring-farrowed gilts in the experiment by Sorenson et al. (1961).

Cronin et al. (1983) reported the incidence of prepubertal gilts by 245 days of age was lower during spring than other seasons and higher during summer than other seasons. Confinement of the gilts was also considered to have played a role in delaying puberty. Christenson (1981) reported a lower proportion of confined and non-confined gilts expressing estrus at nine months of age was seen during the summer months than for those reaching nine months of age during the winter months. Cole et al. (1982) found 160 day-old gilts receiving daily physical boar exposure during the winter months had a longer interval to puberty than gilts exposed during the spring months (8.8 vs. 6.9 days, respectively).

Rampacek et al. (1981), reported time of year may influence the extent of delayed puberty in confined gilts. Gilts were reared in confinement until 100 to 120 days of age, then either moved to a single pen in confinement or to a dirt lot (non-confined). At 150 days of age, estrus detection with a mature boar occurred. In January-March born gilts, 75.4 % of the non-confined gilts and 37.4 % of the confined gilts attained puberty by 270 days. Although differences were not significant in the gilts born in June-July, a higher percentage of non-confined (62.6 %) than confined (50.9 %) attained puberty. Summer months decreased puberty attainment regardless of housing.

Paterson et al. (1989a), noted that the effectiveness of boar exposure to stimulate puberty was decreased during the summer months in two different experiments. In the first experiment, 175-day-old gilts were assigned to receive no boar exposure (control), or 30 minutes of physical boar exposure for either two days per week, five days per week, or seven days per week. Treatments were replicated in summer, fall, and spring. The proportion of control gilts attaining puberty by 235 days of age was significantly lower than boar-exposed gilts in the summer (0.0 vs. 88 %) and fall (44 vs. 92 %), but not in the spring. The interval to puberty was significantly longer for the control gilts in all three replicates than for the boar-exposed gilts. The interval to puberty was similar for all boar-exposed gilts in the summer replicate. However, in the fall and spring replicates, the interval to puberty was significantly longer for the gilts receiving two days of boar exposure per week compared to gilts receiving boar exposure five or seven days per week. The data suggest that the influence of boar exposure is present to a lesser degree in the summer, resulting in a longer interval to puberty. In a similar experiment, Paterson et al. (1989b) noted the effectiveness of boar exposure in the winter and summer when the number of days of boar exposure was limited. Gilts in two herds (Medina herd and Muresk herd) were assigned to no boar exposure or 20 to 30 minutes of physical boar exposure at 165 days of age. Boar exposure occurred for one day, 10 consecutive days or on a daily basis. No effect of treatment or herd was seen on the proportion of gilts attaining puberty (93 %) in the winter. In the summer a lower proportion of control gilts at Medina responded than in the winter (33 vs. 100 %). But no effect of season was observed for the response of boar-exposed gilts. At Muresk, the proportion of gilts attaining puberty in the summer was lower than in the winter for control (0 vs. 86 %), one day (0 vs. 100 %), and 10 day (38 vs. 100 %,). No effect of season was seen on the proportion of gilts responding in the daily exposure treatment (86 %). For maximal boar stimulation, daily boar exposure is necessary. While Paterson et al. (1989b) used 20 to 30 minutes per exposure period, Hemsworth et al. (1988) and Caton et al. (1986) reported that the efficacy of a limited boar exposure regime (less than 30 minutes of exposure per day) was diminished during the summer months.

A third experiment by Paterson et al. (1991) also reported a delay in puberty attainment in both control and boar-exposed groups in replicates beginning in late spring and summer months. Contradictory, under the conditions of an experiment by Philip and Hughes (1995), boar exposure overcame the summer depression in gilt puberty.

Increasing the frequency and duration of boar exposure is beneficial during summer months, but it is likely that the degree to which boar exposure can override any seasonal inhibition is also influenced by genetic and environmental factors.

Trudeau et al. (1988) reported that levels of pheromone 5 α-androstenone, the compound primarily responsible in mediating the boar effect (Pearce et al,. 1988), does not vary in boars on a seasonal basis. This suggests seasonal variation is due to a change in gilt sensitivity to stimuli; however, it is important to note that boar libido does decrease in high ambient temperatures (Pearce et al., 1988). It has been suggested that seasonal patterns of decreased reproductive efficiency were due to an increased sensitivity of the hypophyseal-pituitary axis to the negative feedback activity of estradiol on LH secretion (Almond and Dial, 1990; Smith and Almond 1991).

Gilts born in the spring are slower to reach sexual maturity than those born at other seasons of the year. The climatic conditions of summer delay sexual development in gilts as well. An increased frequency and duration of boar exposure is needed in the summer months to override seasonal inhibition.

Sows weaned during summer and early fall take longer to return to estrus, and more of them remain anestrous than any other time of the year (Claus and Weiler, 1985). Sow farrowing rates often decrease by ten percent during this time compared to winter and spring. Therefore, more gilts are needed to meet farrowing targets (Love et al., 1993). Because climatic conditions may make it difficult for gilts to attain puberty during the summer, a larger, pubertal gilt pool should be established prior to the summer breeding months.

Temperature

One component playing a role in seasonality is temperature. Elevated ambient temperatures cause periods of infertility in all swine. Maksimovic (1983) evaluated the reproductive performance of a gilt pool for 12 months. A lower proportion of gilts expressing estrus was reported for the months of July and August. The proportion of gilts successfully mated was lower for those two months as well.

Chronic heat stress (33.3°C) applied to gilts housed in environmental chambers from 150 to 230 days of age resulted in 80 % of gilts failing to attain puberty. Of the non-heat stressed gilts (15.6°C), 90 % attained puberty. The 80 % of the heat stressed gilts and 10 % of the non-stressed gilts that failed to cycle by 230 days of age were administered 1,000 IU pregnant mare serum gonadotrophin (PMSG; Intervet America, Inc., Millsboro, DE). Ovaries were examined by laparotomy seven days later. An increased incidence of cystic follicles was seen in the heat stressed gilts, as well as a tendency for lower ovulation rates (Flowers et al., 1989). Chronic heat stress conditions (33.3°C) reduce the secretion of gonadotrophins, LH and follicle stimulating hormone (FSH), retarding sexual maturation (Flowers and Day, 1990). Elevated ambient temperatures were reported to increase cortisol (Kunavongkrit et al., 1995) and prostaglandin F-2α concentrations (Gross et al., 1989). Elevated cortisol levels can block ovulation by inhibiting gonadotrophin releasing hormone (GnRH) secretion. Prostaglandin F-2α regresses the corpora lutea, thereby decreasing progesterone to levels undesirable for establishment and maintenance of pregnancy. Another experiment reported that elevated ambient temperatures (32 to 38°C) blocked the stimulatory cue from increased concentrations of estradiol for estrus behavior (Pett, 1988). Alterations in these hormones leads to decreased conception rates and litter size in gilts (Wettemann and Bazar, 1985). A depression in feed intake also results from heat stress, and subsequent growth is retarded due to weight loss and altered energy balance (Armstrong et al., 1986). Social stressors, such as regrouping, magnify this response (McGlone et al., 1987).

The effect of ambient temperature on the ability of gilts to express a second estrus during heat-stress was reported by D'Arce et al. (1970). The proportion of gilts failing to express a second estrus was 0, 2.5 and 8.75 % at ambient temperatures of 26.6°, 30° and 33.3° C, respectively.

Hurtgen and Leman (1980) reported low farrowing rates for gilts mated in July, August and September (60.8 %) compared to the rest of the year (76.9). The seasonal fluctuation was similar for confined and outdoor-housed gilts. Attempts to alleviate heat stress and subsequent mating failures with water sprinkling and evaporative cooling methods were not successful. Bull et al. (1997) evaluated the preference for conductive cool pads, snout coolers and drip coolers by gilts while housed on a metal floor for 10 continuous hours at 34.2°C. Gilts preferred to use the conductive cool pads instead of the snout and drip coolers. Gilts using the cool pads had significantly lower rectal temperatures and respiration rates than the other gilts.

It is important to employ management methods that may mitigate the effects of elevated temperatures, such as providing plenty of water, adequate pig space, and ventilation or shelter.

Photoperiod

Another component of seasonality is photoperiod. The influence of photoperiod on age of puberty and proportion of gilts attaining puberty remains controversial.

Two experiments conducted by Dufour and Bernard (1968) examined the reproductive performance of gilts reared under natural light or in complete darkness. Beginning at eight weeks of age, gilts were reared in pens receiving either natural daylight or complete darkness (except for one hour incandescent light). The experiments began in April and early May. In the first experiment, gilts reared in darkness attained puberty 11 days earlier than gilts reared in natural daylight. The second experiment applied the same light treatments, but half of the gilts were enucleated (eyeballs removed). Age at first estrus was reduced 10 days by darkness, and increased 14 days by enucleation. No differences were seen in growth and carcass traits or in ovulation rate at first estrus for either experiment.

Other experiments have disagreed with this reported advantage of complete darkness. Hacker et al. (1974) reported that a 12 hours light: 12 hours dark regime significantly reduced the age at puberty (183 days) compared to complete darkness (222 days). Awotwi and Anderson (1982) demonstrated that neither complete darkness nor constant light influenced the age at puberty in gilts.

Several experiments have reported the advantage of a long-day photoperiod. Gilts in cool white fluorescent light for 18 hours or gilts in a natural winter photoperiod (nine to 10.8 hours of light) attained puberty significantly earlier than gilts in complete darkness (175.6, 177.1 vs. 193.4 days of age, respectively). Gilts were isolated from mature boars for the entire experiment (Ntunde et al., 1979). Hacker et al. (1979) found gilts in 18 hours of cool white fluorescent light or natural winter photoperiod had an increased ovulation rate compared to gilts reared in complete darkness (13.5, 12.6 and 11.3 corpora lutea, respectively). Hacker et al. (1976) reported that gilts receiving an 18 hour photoperiod attained puberty 42 days earlier than gilts receiving a six hour photoperiod. When a 16 hour photoperiod was compared to an eight hour photoperiod, no significant difference was seen in age at puberty. Lighting was cool white fluorescent (Wise et al., 1981). Kraeling et al. (1983) either put ovariectomized gilts under an 8 hours light: 16 hours dark photoperiod or a 16 hours light: 8 hours dark photoperiod. Neither regime influenced LH secretion in the gilts.

In contradiction to the long-day advantage, Paterson and Pearce (1990) reported the proportion of gilts attaining puberty under a short-day lighting regime (9.5 hours light: 14.5 hours dark) was significantly greater than gilts under a long-day lighting regime (14.5 hours light: 9.5 hours dark). Gilts were isolated from mature boars for the entire experiment. Paterson et al. (1991) evaluated seasonal variation in puberty attainment in isolated and boar-exposed gilts over a 19 month period. A total of 15 replications were conducted at three to six week intervals. Estrus detection with either the back pressure test or mature boar exposure began when gilts were a mean age of 165 days. A higher proportion of boar-exposed gilts reached puberty by 225 days of age than isolated gilts (79.8 vs. 29.8 %), and the interval was shorter for the boar-exposed gilts as well (26.8 vs. 45.1 days). Replicates were assigned into either a long-day (> 12 hour day) or a short-day group (< 12 hour day). The proportion attaining puberty was lower for the long-day group for both the isolated (13.9 vs. 52.6 % for long-day and short-day, respectively) and boar-exposed gilts (74.0 vs. 84.9 % for long-day and short-day, respectively).

Diekman and Hoagland (1983) reported that increasing day length through supplemental lighting failed to hasten puberty in prepubertal gilts. The effectiveness of supplemental lighting may be dependent on season. Diekman and Hoagland (1983) reported that increasing day length to 15 hours with supplemental incandescent lighting did not alter the age at puberty in periods of increasing natural day length (February through July) compared to control gilts with natural photoperiod. However, supplemental lighting during period of decreasing day lengths (August through January) decreased the age at puberty compared to control gilts. Boar exposure hastened the response by 20 days.

Wheelhouse and Hacker (1982) investigated the effect of light source on age at puberty. A 16 hour photoperiod was provided from either a cool white fluorescent, red, ultraviolet, or a full spectrum day light. All lights were set at 65 lux. The only significant effect seen was a delay in puberty under the red light.

The effect of light intensity on age at puberty was investigated by Diekman and Grieger (1988). At 84 days of age, gilts received either (1) supplemental lighting at 1200 lux, (2) supplemental lighting at 300 lux, (3) reduced supplemental lighting (< 10 lux) or (4) a natural lighting (90 lux). The day length for treatment groups 1, 2 and 3 was 15 hours. The photoperiod for group 4 was 9.5 to 12 hours. By 270 days of age, a lower proportion of gilts in the reduced lighting treatment attained puberty (12.5 %) than the other treatment groups (50, 62.5, and 75 % for treatment groups 1, 2, and 4, respectively). It would be reasonable to maintain gilts under natural or cool white fluorescent light for

10 to 12 hours per day. A combination of boar exposure and adequate photoperiod is more stimulatory to gilt puberty attainment than photoperiod alone.

Melatonin regulates the secretion of hypothalamic regulatory factors; such as gonadotrophin releasing hormone (GnRH), which is responsible for the signaling of LH and FSH synthesis and secretion. Diekman et al. (1992) and Bollinger et al. (1997) reported findings that indicate nocturnal rises in melatonin, which are seen in seasonal breeders, i.e. the ewe and the mare, are not necessary for gilts to attain puberty. However, Diekman et al. (1991) reported that consumption of melatonin decreased the age at puberty compared to control gilts (183.8 vs. 194.3 days, respectively). This was seen in gilts reared under short- and long-day periods. But melatonin implants (Wildlife Pharmaceuticals, Ft. Collins, CO), placed subcutaneously in the ear, did not influence the onset of puberty (Diekman et al., 1997).

Housing

The physical and social environments gilts are reared in influence their sexual development. The majority of experiments evaluating the effect of housing on gilt sexual development have compared confinement housing to outdoor housing. Rampacek et al. (1981) reported that rearing gilts in confinement reduced the proportion of gilts attaining puberty by eight or nine months of age by 50 percent, compared to gilts reared in outdoor lots. Christenson (1981) reported that a smaller proportion of gilts in confinement attained puberty between five and nine months of age compared to gilts reared in dry lots (71.3 vs. 85.2 %, respectively). Meacham and Masincupp (1970) reported that gilts reared in open lots attained puberty 15.1 days earlier than gilts reared in confinement.

When crossbred gilts were exposed to a mature boar, fewer gilts attained puberty in confinement compared to gilts that had been relocated to pasture (26.8 vs. 44.6 %, respectively; Caton et al., 1986). The weight at puberty also tended to be greater for confinement reared gilts (Christenson, 1981; Rampacek at al., 1981; Caton et al., 1986).

An interaction between breed and housing was reported by Christenson (1981). More cyclic activity occurred in non-confined gilts at nine months of age than confined gilts, and more cyclic activity occurred in confinement-reared Swedish Landrace x Large White and Hampshire gilts than in confinement-reared Duroc and Yorkshire gilts.

Penning gilts individually or in groups also alters the expression of estrus and cycle maintenance. England and Spurr (1969) reported that confined gilts had a greater occurrence of silent estrus and irregular estrous cycles when penned individually (28 %) versus grouped with eight to twelve gilts per pen (16 %). Five trials over a four-year period revealed that tethered gilts attained puberty an average of four days later than their non-tethered littermates. Expression of estrus was less evident in the tethered gilts and the number of gilts with infantile genitalia at 10 to 12 months of age was significantly greater for tethered gilts (Jensen et al. 1970). Christenson (1984) reported 57 % of gilts penned in groups of three had attained puberty by nine months of age compared gilts penned in groups of 9, 17, and 27, respectively (78, 80 and 81 %). Cronin et al. (1983) reported when group size was greater than 50 gilts at 27 to 28 weeks of age (immediately prior to mating), there was a higher incidence of unmated gilts (12.9 vs. 8.6 %) and an increase in the proportion of unmated gilts showing a negative or low response to the back pressure test than when groups were less than 50 gilts (8.0 vs. 3.6 %). A seasonal effect was seen regardless of group size, with fewer gilts attaining puberty during the summer than in any other season.

Possible reasons for this negative outcome may involve the difficulty of the boar to detect gilts in estrus and for the laborer to maintain efficient records when gilts are penned in large groups. Therefore, extremes in gilt number per pen should be avoided. Penning 10 to 30 gilts together should not hinder attainment of early puberty.

Ford and Teague (1978) determined the effect of floor space per gilt on puberty attainment. Gilts were penned in groups of eight or 12. From 20 to 35 kg, control gilts were allowed 0.37 m^2 per pig. From 35 to 102 kg, space allowance for control gilts was increased to 0.93 m^2 per pig. The performance of these gilts was compared to gilts with either 75 or 50 % of this space. There was no effect on proportion attaining puberty or age at puberty. However, 50 % restriction of the controls led to a reduced average daily gain and feed efficiency. Such depression of growth rate could lead to future reproduction failure. Dial et al. (2001) reported gilt selection rates increased substantially when space allowance was increased from 0.85 to 1.15 m^2 per pig.

Gilts housed in pens adjacent to sow yards expressed estrus at an earlier age compared to gilts isolated from sows (153 to184 vs. 189 to 227 days of age, respectively; Stephens and Close 1984).

Prunier and Mounier (1991) reported the presence of an intact mature sow in the gilt pen influenced the occurrence of estrus in prepubertal Large White gilts. Seven of 19 gilts attained puberty before 225 days of age when exposed to an intact sow compared to zero of 19 gilts responding when exposed to an ovariectomized sow.

Sterle and Lamberson (1996) reported that crossbred gilts exposed to a sow in estrus attained puberty at an earlier age (176.3 days) compared to control gilts (188.1 days). Pearce (1992) investigated the effect of boar exposure versus no boar exposure along with either removing gilts from the pen at the first sign of estrus or leaving the estrual gilts with their pen-mates. Boar exposure started when the gilts were 160 days of age. A better degree of synchrony was reported when estrual gilts were not removed from the pen.

The proportion of gilts attaining puberty is increased when exposed to estrual females. The nature of the stimuli from estrual females is unknown. But Pearce and Paterson (1992) have suggested the response to be mediated by a combination of behavioral (nudging and mounting) and olfactory cues. This method is not as effective as mature boar exposure (Prunier and Mounier, 1991; Pearce, 1992; Sterle and Lamberson, 1996), but unlike boar exposure treatments, the estrual females can be left unsupervised in the pen.

Paterson and Lindsay (1980) reported that gilts reared with contemporary boars attained puberty earlier than gilts raised with barrows if no boar exposure was provided (196.6 vs. 220.3 days, respectively).

Air quality is an important aspect to gilt development. Gilt performance is compromised when reared in an aversive gaseous environment. Malayer et al. (1987) reported that manure gases influenced attainment of puberty in gilts reared in confinement from 10 to 40 weeks of age. Crossbred gilts were reared on concrete slats over a deep pit where manure was either drained and refilled with clean water biweekly (clean) or allowed to accumulate (control). Between 20 to 40 weeks of age gilts were exposed to a boar three times a week. Ammonia concentrations were four-fold higher in the control room than in the clean room (21 vs. 5 ppm, respectively). A higher proportion of gilts in the clean room attained puberty by 24 to 26 weeks of age than the control group. However, the secretory patterns of LH and FSH were not altered by treatment. Therefore, the decreased estrus response in the control gilts was due to a decreased sensitivity to boar pheromones. In a similar study, gilts were reared in either the clean or control room from 10 to 30 weeks of age. From 26 to 28 weeks of age, the gilts were exposed to a mature boar daily, and from 28 to 30 weeks of age gilts were boar-exposed every other day. Ammonia concentrations in the control room were three- to five-fold higher than the clean room (19.7 vs. 7 ppm, respectively). A greater proportion of gilts in the clean room attained puberty within seven days after initiation of boar exposure (Malayer et al. 1988). Diekman et al. (1993) did not report an effect of ammonia concentration on onset of puberty. However, average daily gain was significantly less in ammonia concentration of 35 ppm than in lower concentration of 7 ppm. Gilts become restless and irritable when sustained exposure of ammonia concentrations is greater than 10 ppm (Jones et al., 1996). Prolonged exposure to high ammonia levels can alter growth and sexual maturation.

Transportation

Transportation, relocation and mixing expose gilts to vibrations and unfamiliar noises, odors and animals. For this reason, these stimuli can be used to induce puberty in gilts. However, results have been variable and confounded with other factors.

Signoret (1970) reported transportation resulted in gilts expressing estrus within a few days. This was seen in the absence of boar exposure. Diekman and Trout (1984) reported that gilts that were relocated from confinement to dirt lots and received boar exposure exhibited estrus 3 to 6 days afterwards.

An experiment by Bourn et al. (1974), found that the combination of mixing, transportation, relocation and boar exposure play a role in sexual maturity in gilts. Gilts received boar exposure at either 135 or 165 days of age without being removed from their pen or after being mixed and transported 2.8 km to a new pen. Boar exposure at 135 days of age led to earlier puberty, and the combination of transportation and boar exposure was more effective than boar exposure alone. Similar findings were reported by Bourn et al. (1976).

It was demonstrated by Scheimann et al. (1976), that a greater proportion of gilts that had been mixed and relocated attained puberty within seventeen days than gilts that were only relocated (26 vs. 0 %). And with the addition of boar exposure, more mixed and relocated gilts receiving boar exposure responded than relocated gilts receiving boar exposure (88 vs. 79 %). When gilts were assigned to receive either mixing (M), transportation (T), relocation (R), or boar exposure (E), the proportion of gilts that responded within 10 days were 7.2 (MT), 8.3 (MT), 28 (MTR) and 87 % (MTRE; Zimmerman et al 1976). Eastham and Cole (1987) reared gilts in confinement with fence-line boar exposure. At 160 days of age, gilts were either relocated or not and provided physical boar contact for estrus detection. The gilts that were relocated attained puberty earlier than non-relocated gilts.

In four series of experiments, Stephens and Close (1984) assigned one hour treatments to gilts over a 9 to 11 week period. Treatments were either: noise, vibration, noise and vibration, or relocation near sow yard. The noise and vibrations components were applied with a transport stimulator. Simulated transportation (noise and vibration, alone or in combination) did not have an effect on induction of early puberty in the gilts. Relocating gilts near the sow yard did have a significant effect on reducing age at puberty. A similar study assigned two hour treatments to gilts over a 25 to 56 day period. Treatments were either: noise, vibration, noise and vibration, road journey along country roads, or relocation near sow yard at 120, 140 or 160 days of age. Neither transportation nor simulated transportation had a significant effect on age at puberty compared to relocation near the sow yard (Stephens and Close 1986).

Zimmerman et al. (1974) evaluated the age of gilt at boar exposure and relocation on puberty attainment. Treatment was more effective at 125 days than 150 or 175 days of age. Eastham et al. (1986) relocated crossbred gilts from confinement to straw-bedded pens in partially covered outdoor lots adjacent to a mature boar. Thirty minutes of boar exposure was initiated at either 160, 180 or 200 days of age. Relocation and boar exposure at 160 days of age led to earlier puberty compared to 180 and 200 days. In an experiment conducted by Caton et al. (1986), gilts were moved from confinement to pasture at three different ages (100, 149, and 180 days of age). Moving gilts from confinement to pasture to induce puberty in gilts was more effective at 180 days of age than 140 or 200 days (187.0 vs. 192.0 and 190.5 days of age at puberty, respectively).

Signoret et al. (1990) reported transportation, combined with a new environment and boar exposure at 169 days of age, induced estrus in 72.6 % of gilts within seven days after being transported 160 km. Hughes et al. (1997) reported that transport alone does not provide a significant stimulus for early puberty attainment in gilts. However, a combination of frequent boar exposure and transport may result in a greater degree of gilt puberty stimulation than frequent boar contact alone. The response however, was considerably lower than seen in Signoret et al. (1990). Differences in response are likely to reflect either genotype differences, variations in the boar exposure stimulus, or differences in the transportation. Transport stress provided by Hughes et al. (1997) was daily loading into a trailer for the first ten days of the experiment and driven at a constant speed (70 kmh) for 20 min. Transportation, relocation and mixing are methods suggested to act additively with boar exposure.

Exogenous Hormones

Another method used to induce estrus and ovulation is the administration of exogenous hormones. Hormones are used to mimic the natural events responsible for the onset of puberty. The ovarian follicles containing the eggs are stimulated to grow by follicle stimulating hormone (FSH). As the follicles mature they release estradiol. Estradiol signals the release of luteinizing hormone (LH) which triggers ovulation.

Progesterone Pretreatment

In *Bos Taurus* cattle, increased progesterone is thought to be a prerequisite for the development of normal estrous cycles. Berardinelli et al. (1979) reported that progesterone increased during the initiation of puberty in heifers, and Rawlings et al. (1980) reported progesterone increases before postpartum beef cows returned to estrus. Gonzalez-Padilla et al. (1975) used progestins to induce estrus in prepubertal heifers, and

Anderson et al. (1996) noted that an increase in LH pulses occurred in response to progestin treatment. The LH activity results from a decrease in the negative feedback actions of estradiol on GnRH secretion, thereby increasing the concentration of gonadotrophins in circulation.

Diekman and Trout, (1984) looked at the secretory pattern of progesterone in prepubertal gilts that had been relocated and exposed to a mature boar. A small increase in progesterone prior to the first estrus of the prepubertal gilts was seen. However, no subsequent increase in LH or FSH was observed, so Diekman and Trout (1984) concluded that pubertal estrus was not dependent on or necessary for the attainment of puberty in gilts. A similar experiment by Esbenshade et al. (1982) did not report a rise in progesterone before or during the pubertal follicular phase, also suggesting that progesterone priming may not be prerequisite to puberty in gilts.

Gilts exhibit greater ovulation rates during the second and third postpubertal estrus, compared with the pubertal estrus (Self et al., 1955; Zimmerman et al., 1960). It has been suggested that previous exposure to progesterone enhances fertility during subsequent estrus.

Nephew et al. (1994) exposed prepubertal gilts to eight days of progesterone (100 mg per day, intramuscular) prior to receiving 750 IU PMSG one day later. An improvement in follicular development and ovulation rate was reported. However, no beneficial effect was reported when PG-600 was given after progesterone treatment (100 mg per day, i.m., for 2 days). However, the proportion of gilts pregnant by day 10, the number of embryos recovered per gilt, and embryonic survival were reduced with both progesterone treatments.

Exposure to progestin implants (norgestomet, Sanofi Animal Health, Overland Park, KS) for nine days prior to PG-600 administration did not enhance expression of estrus or ovulation rate compared to gilts receiving PG-600 alone (Knox and Tudor 1999). Estienne et al. (2001) pretreated prepubertal gilts with Regu-mate (15 mg per day; Intervet, Millsboro, DE) for 18 days. PG-600 was administered 24 hours following the end of the feeding regime. The proportion of gilts expressing estrus within seven days of PG-600 administration and the injection-to-estrus interval were similar to gilts receiving PG-600 only. No differences were seen in ovarian characteristics. Progesterone pretreatment in prepubertal gilts results in no beneficial effect on the ovarian responses to PG-600.

Estrogens

Another method of inducing puberty is the use of estrogenic steroids to mimic the rise in estradiol that naturally occurs prior to ovulation. Reports on the proportion of gilts ovulating and the level of subsequent fertility in gilts treated with estradiol benzoate have been variable.

Yang et al. (1987a) treated crossbred prepubertal gilts with five different doses (5, 10, 15, 20 or 25 μg estradiol benzoate per kg body weight) at 140 days of age. The proportion of gilts ovulating within 10 days was similar among treatments. The overall proportion of gilts ovulating was 77.5 %. This response was higher than gilts treated at 140 days of age (60 %) in an experiment by Hughes and Cole (1978). The duration of standing estrus was positively correlated to the dose ($r = 0.98$; Yang et al., 1987a). A positive relationship between dose and duration of estrus was also observed by Dial et al. (1983). Of the gilts attaining puberty (first ovulation and expression of estrus), 75 % had a subsequent ovulation by 235 days of age, but 20 % of those gilts failed to express estrus. The remaining proportion of gilts expressed estrus outside of the normal estrous cycle duration (18 to 23 days). The interval from first estrus to second estrus for these gilts was 41.5, 47.0, 37.4, 58.5 days, and 31.0 for 5, 10, 15, and 25 µg estradiol benzoate per kg body weight, respectively. There was no significant difference between treatments for ovulation rate at the second estrus (Yang et al., 1987a). Yang et al. (1987b) demonstrated the addition of Regu-mate or Regu-mate and boar exposure helps to enhance the proportion of gilts expressing a second estrus within the normal range.

Paterson et al. (1984) reported that 91.3 % of treated gilts ovulated when given 1.2 mg estradiol benzoate at 174 days of age. This was a higher proportion than Yang et al. (1987a) and Hughes and Cole (1978). Response to estradiol benzoate may be dependent on age. Yang et al. (1988) administered a daily dose of 6 µg estradiol benzoate (per kg body weight) for three consecutive days to gilts beginning at either 100, 120, 140, 160, 180 or 200 days of age. Gilts were exposed to daily physical boar contact. The proportions of gilts ovulating within 10 days of injections were 60, 20, 0, 0, 60 and 20 % for 100, 120, 140, 160, 180 and 200 days of age, respectively. This response was low and highly variable.

Kirkwood and Thacker (1988) reported that estradiol benzoate induced 100 % of gilts treated at 150 or 170 days of age to express estrus. But only 68 and 60 % ovulated (150 and 170 days of age, respectively). A low response was seen for a subsequent estrus (33 and 60 % for 150 and 170 days of age, respectively).

While estradiol benzoate stimulated estrus at an earlier age than exposure to mature boars, more gilts expressed estrus without ovulation (32.7 vs. 14.1 %), had a decreased ovulation rate (6.2 vs. 12.8 corpora lutea), and had a higher incidence of cystic follicles (11.9 vs. 0.8 %; Dyck, 1988).

Treatment with estradiol benzoate will induce estrus, but will not necessarily maintain a normal estrous cycle. The level of ovarian development at time of induction will determine the response to the LH surge (Kirkwood and Aherne 1988). Breeding at an estradiol benzoate induced estrus would not yield desirable results because of the reduced ovulation rate (Dyck 1988).

PG-600

Pregnant mare serum gonadotrophin (PMSG) and human chorionic gonadotrophin (hCG) are two hormones similar to FSH and LH in swine, and when administered, stimulate follicular development and ovulation. Experiments using gonadotrophins have demonstrated a large variation in response rate.

Baker and Coggins (1966) conducted two experiments using gonadotrophins on crossbred prepubertal gilts between 100 and 180 days of age. In experiment one, gilts were given 2,000 IU PMSG or a combination of 1,000 IU PMSG and 500 IU hCG. Treatment with PMSG alone failed to induce ovulation, while the combination treatment induced ovulation in nine of 14 gilts. In the second experiment, gilts were treated with 250; 500; 1,000 or 2,000 IU PMSG. Administration of PMSG was followed by 500 IU hCG 48 hours later. All gilts ovulated and ovulation rates increased linearly with PMSG dose. No mention was made concerning the behavior of the gilts at estrus. While the first experiment of Baker and Coggins (1966) reported failure of treatment with PMSG alone to induce ovulation, Hurtgen and Johnston (1983) reported a better response from four gilts with delayed puberty when given 500 IU PMSG. Three of the gilts expressed estrus an average of four days after treatment and ovulated. The remaining gilt remained anestrous and did not ovulate.

While treatment with PMSG, alone or in combination with hCG, can induce puberty, it has been demonstrated that treatment with hCG alone is not effective. Esbenshade and Day (1981) conducted an experiment to determine the effect of hCG on the incidence of estrus in prepubertal gilts reared in confinement. At 191 days of age, gilts were given saline or 250 IU hCG. Gilts were then relocated to new pens and checked with a boar twice daily for estrus for 10 days. Treatment with hCG had no effect on the proportion of gilts cycling within 10 days.

Schilling and Cerne (1972) reported that a combination of 400 IU PMSG: 200 IU hCG induced greater than 90 % of prepubertal gilts, in three different groups, to express estrus within three to seven days, followed by a high conception (80 %) and farrowing rate (76 %). A high degree of synchrony was seen at the second and third estrus for gilts not mated at pubertal estrus. Two groups were Swedish Landrace five to 6.5 months of age and the third group was German Landrace 5.5 to six months of age. Guthrie (1977) treated five gilts with a single injection of 400 IU PMSG: 200 IU hCG and five gilts with 1,000 IU PMSG alone. All gilts receiving the combination treatment and four of five PMSG gilts ovulated. Gilts in the combination treatment had a greater ovulation rate (23.2 corpora lutea) than PMSG gilts (6.8 corpora lutea). None of the gilts expressed estrus even though estrus detection was conducted daily with a mature boar. This was dramatically different than the high proportion of gilts expressing estrus reported by Schilling and Cerne (1972).

Karalus et al. (1990) allotted at total of 47 Landrace gilts into three age/weight groups: light (L), 16 gilts less than 120 days old and between 45 to 55 kg; medium (M), 16 gilts between 130 and 150 days old and between 60 and 70 kg; and heavy (H), 15 gilts greater than 160 days old and between 75 and 85 kg. Gilts were treated with 750 IU PMSG followed by 500 IU hCG 72 hours later. Forty-six gilts expressed estrus and ovulated. The one gilt that failed to express estrus and ovulate was in the L group. Although all but one of the youngest gilts (group L) ovulated in response to the treatment, only three continued to cycle. The intermediate group (M) had a similar response. Thirteen out of 15 of the oldest gilts (H) expressed a second estrus and ovulated. This suggests a relationship between age and weight on the response to treatment with gonadotrophins. An experiment by Paterson et al. (1984) demonstrated that although gilts responded to PG-600 as early as 120 or 130 days of age, maintenance of cyclic activity or pregnancy was extremely poor. Tilton et al. (1995) reported an increased incidence of cystic follicles in gilts induced at 140 days of age. It appears the ability to express estrus and ovulate in response to exogenous hormones depends on the physiological maturity of the gilt; therefore, hormones need to be administered when the gilt is nearing puberty.

After promising results with the use of low dose combinations of PMSG and hCG (Shilling and Cerne, 1972), a commercial preparation was made. PG-600 (Intervet, Millsboro, DE) is a commercially available product containing 400 IU PMSG and 200 IU hCG. It is recommended by the manufacturer that gilts be at least 5.5 months of age and weigh a minimum of 85 kg when using PG-600. Using gilts meeting the manufacturer's criteria, Knox and Tudor (1999) reported a greater proportion of PG-600-treated gilts expressed estrus (69 %) and ovulated (65 %) within 45 days of PG-600 administration than did control gilts (34 and 13 %, respectively). PG-600 gilts also attained puberty 10 days earlier than controls.

The variations reported in gilt response to treatment with gonadotrophins have often been due to gilts either ovulating without expression of estrus, expressing estrus with ovulating or remaining anestrous. There have been several experiments demonstrating improved estrus expression and maintenance of cycle with the presence of boars before and after the gonadotrophic-induced estrus. Paterson and Lindsay (1981) conducted two 2 x 2 factorial experiments using PG-600 and full boar exposure on prepubertal crossbred gilts. Treatments were carried out to the second estrus to evaluate treatment effect on cycle maintenance. Gilts were between 155 and 165 days of age when treatments were initiated. In experiment one, five out of seven gilts receiving PG-600 ovulated without expressing estrus; whereas, all gilts receiving PG-600 with boar exposure ovulated and expressed estrus. In experiment two, a larger proportion of gilts returned to a second estrus in the PG-600 and boar exposure group (87 %) than in the group only receiving PG-600 (52 %). Of the gilts returning to estrus in both PG-600 groups, the proportion ovulating was not significantly different between PG-600 treatments. Collectively, gilts receiving PG-600, alone or in combination with boar exposure, had a significantly shorter interval to first estrus than gilts receiving only boar exposure and control gilts. At the time of second estrus, the presence of a boar, in conjunction with PG-600, increased the proportion of gilts expressing a second estrus. A follow-up experiment was conducted by Paterson and Martin (1981). Between 156 and 159 days of age, nineteen gilts received PG-600 and were allotted into groups either receiving fence-line boar exposure (10 gilts) or no boar exposure (9 gilts, control). At first estrus all 10 gilts receiving boar exposure expressed estrus and nine ovulated. A similar response was seen at first estrus with control gilts. The maintenance of cyclic activity was poor, with only four boar-exposed gilts expressing estrus and ovulating and only two control gilts expressing estrus and one ovulating. This response at second estrus was lower than the response reported by Paterson and Lindsay (1981); however, the presence of boars still enhanced cyclic activity compared to control, though not to a significant degree.

Burnett et al. (1988) reported that treatment with PG-600, in addition to mixing, relocation and boar exposure induced an earlier and more synchronous puberty in gilts than treatment with PG-600 alone. Gilts were mated at pubertal estrus and no effect of PG-600 treatment was seen on litter size at 35 days of pregnancy. Holtz et al. (1999) mated gilts that were induced with PG-600 at pubertal or second estrus and compared their performance to the non-treated gilts mated at pubertal estrus. Litter size was significantly reduced in PG-600 gilts mated at pubertal estrus. The performance of the gilts at second and third parity did not differ among the three groups. Britt et al. (1989) treated gilts aged 5.5 to 7.5 months on 10 different farms with PG-600 at the time they were moved from finishing facilities to breeding pens. Gilts were classified as light or heavy if they were below or above the median weight for the farm. The proportion expressing estrus within 28 days was 72.9 and 59.5 % for PG-600 and non-treated (control) gilts, respectively. Within seven days, 57.5 % of the PG-600 gilts were in estrus compared to 40.9 % of the controls. The mean interval to estrus was shorter for PG-600 gilts (7.5 days) compared to control gilts (10.4 days). A larger proportion of heavy gilts expressed estrus within 28 days than light gilts (77.7 vs. 62.3 %). No other trait differed between the weight classes. Gilts were mated once daily at pubertal estrus, and farrowing rate and the number of pigs born alive were similar for both groups.

Breen et al. (2005) conducted two experiments evaluating the effectiveness of boar exposure prior to PG-600. The first experiment evaluated whether 30 minutes of either physical boar exposure or fence-line exposure for 19 days prior to PG-600 injection was more effective for inducing puberty in gilts. Gilts were 150 days of age when boar exposure was initiated, and gilts that expressed estrus during the 19-day exposure period were removed from the study (five gilts receiving fence-line boar exposure and seven gilts receiving physical boar exposure). After PG-600 treatment, estrus detection occurred twice daily. There was no difference between boar exposure methods on estrus (77 %), age at puberty (170 days), interval to estrus (4 days), gilts ovulating (67 %) or ovulation rate (12 corpora lutea). The second experiment evaluated the effect of either four days of fence-line contact (30 minutes per day) or no boar exposure (control) and gilt age (160 or 180 days of age) on response to PG-600. After PG-600 treatment, gilts were checked for estrus twice a day with fence-line boar exposure. There was no effect of age group on estrus (55 %) or interval to estrus (4 days). A greater proportion of boar-exposed gilts expressed estrus (65 vs. 47 %), had a shorter interval to estrus (3.6 vs. 4.3 days), and reached puberty earlier (174 vs. 189 days of age) compared to control gilts. Under the conditions of these experiments, fence-line boar exposure, in conjunction with PG-600, is an effective method to induce puberty.

Knox et al. (2000) observed that the majority of past experiments administered PG-600 intramuscularly (i.m.) as opposed to subcutaneously (s.c.; Schilling and Cerne, 1972; Paterson and Martin, 1981; Britt et al., 1989). It was demonstrated that s.c. administration of PG-600 significantly increased the proportion of gilts expressing estrus compared to i.m. administration and controls (76 % vs. 52 and 15 %, respectively). Both PG-600 treatments reduced the interval to estrus (4.6 days) compared to control gilts (5.9 days) (Knox et al., 2000).

The effect of PG-600 dosage on prepubertal gilts was evaluated by Breen et al. (2006). Gilts were administered one (1.0X), one and one-half (1.5X), or two (2.0X) doses of PG-600 (s.c. or i.m. injection). The proportion of gilts expressing estrus within 20 days (58 %) was not affected by dose or route. This is not in agreement with a previous report that indicated s.c. injection of PG-600 induced a higher estrus response than i.m. injection (Knox et al. 2000). This estrus response of 58 % was comparable to previous studies (Paterson et al. 1981; Tilton et al. 1995; Knox and Tudor, 1999), but was below optimal. The proportion of gilts ovulating, the interval to estrus, and duration of estrus were not affected by dose or route. Ovulation rate was influenced by dose, but was similar between routes. Increasing the dose of PG-600 increased ovulation rate, but using the 2.0X dose caused a significantly larger number of follicular cysts. It may be beneficial to increase the dose to 1.5X if an increased ovulation rate is needed for embryo collection, but a higher dose would not be recommended.

It was demonstrated by Tilton et al. (1995) that gilt lines selected to differ in physiological maturity responded differently to gonadotrophin treatment. A greater proportion of gilts from a line selected for early puberty expressed estrus within five days after PG-600 treatment than gilts under relaxed selection (69.9 vs. 29.6 %, respectively).

Britt et al. (1989) reported no significant difference between gilts (165 to 225 days of age) induced with PG-600 and control gilts regarding the proportion of gilts that returned to estrus after mating at pubertal estrus, the proportion farrowing, pigs born alive and dead per litter, pigs weaned per litter, wean-to-estrus interval and the proportion in estrus after weaning. Iwamura et al. (1998) compared the reproductive performance of PG-600-induced gilts at 152 days of age to non-treated controls. After PG-600 treatment, 85.2 % of gilts expressed estrus within six days, and the interval to estrus was 3.7 days. Gilts that responded to PG-600 treatment were artificially inseminated at pubertal estrus, and the controls were inseminated at the time spontaneous puberty was attained. The farrowing rates were similar between the groups. However, litter size was reduced for the PG-600 gilts. This most likely resulted due to the uterus not being fully mature because the induced-gilts were younger at mating than the control gilts, suggesting it would be beneficial to mate at second or third estrus when gilts are more mature. The gilts used by Iwamura et al. (1998) were younger than those used in Britt et al. (1989) and were Large White rather than crossbred.

PG-600 is also approved for use in sows on day of weaning to prevent anestrus or eight to 10 days after weaning to treat anestrus. Estienne and Hartsock (1998) reported PG-600 increased the proportion of sows in estrus within seven days after weaning (97 and 83 % for PG-600 and controls, respectively). Estrus was expressed sooner in sows given PG-600 relative to controls (3.8 vs. 4.5 days). Similar results were reported by Vargas et al. (2006) with additional data on the size of the subsequent litter. Sows treated with PG-600 24 hours after weaning birthed 11.2 pigs in the subsequent litter compared to 10.4 pigs birthed by non-treated sows. This was a significant difference. DeRensis et al. (2003) treated sows with PG-600 two days pre-weaning or on the day of weaning. No difference was seen between PG-600 treatments. Compared to non-treated controls, the wean-to-estrus interval was significantly shorter for both PG-600 groups and no treatment effect was apparent for subsequent farrowing rate and litter size.

Age and Estrus Number at Mating

Van Wettere et al. (2006) reported no significant effect of mating at pubertal or second estrus or age of gilts at mating (161, 182 and 203 days of age) on ovulation rate, embryo number or embryo survival. An experiment by Hughes and Cole (1975) also reported no significant effect of age at puberty on conception rate, embryo survival to 20 days or pregnancy rate at 20 days. But several experiments suggest that estrus number at first mating has an effect on ovulation rate and number of piglets born. Self et al. (1955), Zimmerman et al. (1960) and Archibong et al. (1987) reported that ovulation rate increased with subsequent estrous cycles after puberty. Warnick et al. (1951) and Archibong et al. (1987) found that mating at pubertal estrus decreased embryo survival. Dial and Bevier (1986) reported that gilts mated at pubertal estrus produced 1 to 1.5 fewer pigs born alive in the first litter than gilts mated at second estrus. After four litters, Young et al. (1990) reported gilts bred at second estrus had one point three more pigs born alive compared to gilts bred at pubertal estrus. When gilts were bred at the same weight and age, similar results were seen, indicating the increased litter size was independent of age and weight at breeding (Patterson et al. 2005).

Because litter size can be lower for gilts mated at first estrus, PG-600 can be used to synchronize a group of gilts in order to mate at the second or third estrus after induction (Schilling and Cerne, 1972).

Estrus Synchronization in Cyclic Gilts

After gilts attain puberty and begin to express normal estrous cycles, boar exposure and PG-600 are not effective in synchronizing estrus. The primary reason for this is due to the presence of progesterone in high concentrations during the majority of the estrous cycle. The effects of boar exposure and PG-600 can not trump the suppressive effect progesterone has on follicular development. Therefore, methods for synchronizing estrus in cycling gilts need to decrease or remove progesterone at the same time in all gilts.

Regu-mate is an orally active, synthetic progestin effective in the synchronization of estrus in sows and sexually mature gilts that have had at least one estrous cycle (Kraeling et al., 1981). Kraeling et al. (1982) reported that Regu-mate had no inducing or synchronizing effect on prepubertal gilts.

Davis et al. (1976) found that treating cycling gilts with Regu-mate for 18 days at 10-15 mg per day resulted in a mean time to estrus of 4.5 to 5.2 days. Stevenson and Davis (1982) compared estrus activity in mature gilts fed 15 mg per day of Regu-mate for either 14 or 18 days. The intervals from the last day of feeding to estrus were similar between the two groups (5.4 ± 0.1 and 5.3 ± 0.1 days for 14-day period and 18-day period, respectively). The proportion of gilts expressing estrus between four and nine days after treatment was nearly identical (96 % and 97 %). This experiment indicates that reducing the feeding period from 18 to 14 days did not affect the synchrony of estrus.

Two other experiments reported tight synchrony in mature gilts with the 14-day feeding regime. Rhodes et al. (1991) reported 90 % in estrus between four and 10 days after treatment. The interval from the last feeding of Regu-mate to estrus was 7.4 days. Wood et al. (1992) reported that 92 % of gilts expressed estrus within seven days and 98 % within 10 days. The mean interval was 5.5 days.

The effectiveness of feeding Regu-mate in mature, post-pubertal gilts on synchronization has been clearly demonstrated. However, it is also important to note the fertility of gilts mated after synchronization. Martinat-Botte et al. (1990) reported a significant improvement in farrowing rate following treatment with Regu-mate (88.4 % vs. 80.8 % for Regu-mate and controls, respectively). There was a seasonal effect on farrowing rates in both treatments during the summer. It was also reported that litter size was significantly increased by 0.5 piglets (9.6 vs. 9.1 piglets for Regu-mate-treated and control gilts respectively). In contrast to this, no significant differences in farrowing rate, litter size born, or number of pigs born alive for Regu-mate-treated gilts and control gilts were reported in other experiments (Kraeling et al., 1982; Stevenson and Davis, 1982; Rhodes et al., 1991; Wood et al., 1992).

Regu-mate is approved for use only in horses in the United States. Swine producers can now use Matrix (Intervet, Millsboro, DE). The dosage and feeding regimes for Matrix are unchanged from those used with Regu-mate in experiments. Patterson et al. (2006) demonstrated the efficacy of Matrix in synchronizing estrus. Matrix was fed to gilts for 14 days (15 mg per day). Within 10 days following withdrawal, 91.3 % of the treated gilts expressed estrus and were bred. It may be advantageous to use a program of PG-600 and Matrix to help fulfill a breeding goal. If replacement gilts are not cycling, PG-600 will induce estrus. If gilts are not mated at their first estrus, Matrix may then be used to synchronize them as tightly as needed.

CHAPTER III

ESTRUS INDUCTION AND MAINTENANCE OF CYCLES IN GILTS WITH PG-600 AND BOAR EXPOSURE

ABSTRACT

The ability to induce puberty in gilts at an earlier and predictable age can facilitate introduction into the breeding herd. One method to initiate puberty (PG-600; 400 IU of PMSG and 200 IU of hCG, Intervet, Millsboro, DE), elicits estrus in a majority of gilts. However, a proportion of those gilts do not recycle normally. This study looked at the efficacy of PG-600 and boar exposure, alone and in combination, to induce and maintain regular cycles. Two replicates of 160 gilts each (182 days old) were conducted on a commercial farm in June and July, 2006. Replicates were combined for analysis. Gilts were presumed prepubertal on arrival from the multiplier and randomly assigned to one of four treatments in a 2 x 2 factorial arrangement: PG-600, weekday 10 min of full physical contact boar exposure (BE), PG-600 + BE, and neither PG-600 nor BE (control). Initial weight and backfat measurements were taken. Detection of estrus was performed during BE or during two min of fence-line boar exposure. Gilts were considered in estrus when they stood to be mounted. A total of six gilts were removed from the experiment for health reasons. The PG-600 and PG-600 + BE gilts had a higher ($P < 0.0001$) percentage in estrus within seven days than the BE and control treatments (69.4 ± 7.04 %, 80.8 ± 7.04 % versus 25.1 ± 7.04 %, 12.5 ± 7.04 %, respectively). Eighty-five of 146 gilts in estrus within seven days returned to estrus 18 to 23 days later. Although the BE and control groups had fewer gilts respond within seven days, a larger proportion recycled within 18 to 23 days; (100 ± 9.74 % of BE versus 78 ± 9.74 % control and, 55.8 ± 9.11 % and 50 ± 9.11 % for PG-600 and PG-600 + BE respectively). Half of control gilts showed estrus within 30 days regardless of initial weight. PG-600 and BE gilts with heavier initial weights had a higher probability of coming into estrus. Heavier gilts in the PG-600 + BE group had a lower probability of cycling. Similar probabilities were seen for initial age. Gilts that expressed estrus within 30 days in all treatment groups did so regardless of back-fat thickness. There was no significant difference among treatments regarding first farrowing rate and litter size. The greatest response was to PG-600. Response to BE is dependent on many factors, and in this study was lower than expected. Addition of daily boar exposure to PG-600 did not result in dramatic increase in proportion maintaining cycles and may not be warranted.

Introduction

Having more gilts attaining puberty at predictable times permits more efficient scheduling of breeding and farrowing facilities and allows for the introduction of gilts into breeding groups. Puberty at an early age can reduce the number of non-productive days and increase the number of pigs born per animal (Dial et al., 2001). There are many management practices that influence gilt age at puberty; one method being the exposure of gilts to a mature boar (Hemsworth et al., 1988). The most influential components of boar exposure in the attainment of puberty are smell (pheromones) and physical contact (Pearce and Hughes, 1987). Boars with high libido are best for stimulating a strong estrus response (Hughes 1994), and daily physical boar contact for 10 minutes can be effective if adequate pen space is provided (Paterson et al., 1989b). While producers are aware of the benefits of boar exposure, it is not widely implemented due to time and labor constraints. The use of the commercially available product PG-600 may be applied more favorably by producers than boar exposure, as a single injection can elicit estrus in a high proportion of gilts (Britt et al., 1989). However, a proportion of those gilts will not ovulate or exhibit a second estrus 18 to 23 days later (Paterson and Martin, 1981). The addition of daily boar exposure has been reported to remedy this problem by enhancing cyclic activity and estrus expression (Paterson and Lindsay, 1981). The objective of the present study was to determine the efficacy of PG-600 and boar exposure, alone and in combination, on estrus induction and maintenance of cycles in a commercial setting. It was expected that the gilts receiving both boar exposure and PG-600 would have the youngest and most synchronous estrus. The groups receiving only one of the treatments were expected to be intermediate, and the group not receiving either was expected to be both older and the least synchronous.

Materials and Methods

Experimental Animals

Two replicates of 160 gilts each were conducted on a commercial farm in June and July, 2006. The gilts were Fertilis 30 maternal line hybrid females from Genitiporc (Alexandria, MN), were a mean age of 182 days, and were presumed prepubertal on arrival from the multiplier. Gilts were transported from Pratt, Kansas to Marshall, Missouri (576 km, 5 h 39 min). All gilts were randomly assigned to one of four treatments in a 2x2 factorial arrangement: PG-600; weekday 10 minutes of full physical contact boar exposure (BE); PG-600 + BE; and neither PG-600 nor BE (control). Gilts were penned by treatment in groups of 10 in a naturally ventilated barn and given ad libitum access to feed. Pen dimensions were 2.74 m x 4.26 m with 1.16 m^2 per gilt. Treatments were initiated on the day following arrival. PG-600 was administered by way of a 5 ml intramuscular injection in the neck by farm staff.

Initial weight and backfat thickness were measured on the day of treatment initiation and subsequent measurements were collected on a weekly basis. Backfat thickness was measured using the Renco Lean-Meater (Renco Corporation, Minneapolis, MN) at the location of the tenth rib. To ensure consistent readings from week-to-week, hair was shaved from the area to mark the location and to assure proper contact between the probe and skin.

The mature boar providing exposure for treatment groups and estrus detection was penned adjacent to the heat check pen, located a distance of 5.48 m from the closest gilts, so as not to influence treatment response. The same boar was used for both replicates.

Estrus Detection

Estrus detection was performed either during BE treatment or during two min of fence-line boar exposure. As gilts were checked for estrus, a record was kept by using a legend to describe how the gilts looked and behaved (Table 1). Gilts were considered in estrus when they expressed a standing reflex. Weekend estrus detection for all treatment groups was two minutes of fence-line contact, with the exception of the first week for each replicate, where full treatment was applied. Scheimann et al. (1976) and Van Lunen and Aherne (1987) reported a higher proportion of gilts attained puberty when gilts were moved to boar pens compared to when boars were moved to gilt pens for estrus detection. In the present study, gilts were moved to the estrus-check pen, adjacent to the boar pen, for estrus detection.

Dates of first and second estrus were recorded for gilts responding within 30 days after initiation of treatments. No blood samples were taken to measure progesterone concentration and no laparoscopy was performed to prove ovulation. These procedures are unlikely to be performed under commercial settings and preliminary data indicated they may contribute to puberty induction. At the end of the 30 day treatment period, the gilts were moved to the acclimation barn, and from there, they entered the breeding herd. Their performance in the herd was observed and recorded by the farm employees, and farrowing rate and litter size were reported for analysis to ascertain if an effect of treatment existed.

Statistical Analysis

Because there were no significant effects ($P > 0.05$) of replicate, replicates were combined for analyses. The statistical analyses were run with the GLM and GENMOD procedures of SAS (SAS Inst. Inc., Cary, NC). The model for calculating Least-Squares Means included treatments (absence or presence of PG-600 and BE) and the interaction between treatments. The model for calculating the probability of animals expressing estrus included interactions between treatment and weight, age and backfat thickness.

Results and Discussion

Six gilts were removed from the experiment for health reasons (2 gilts each from the PG-600, PG-600 + BE and BE treatment groups). Data for these gilts were not included in the analysis.

A total of 146 of the 314 gilts comprising the experiment expressed their first estrus within seven days following the initiation of treatments. PG-600 and PG-600 + BE gilts had a higher ($P < 0.0001$) percentage in estrus within seven days than the BE and control treatments (69.4 ± 7.04 %, 80.8 ± 7.04 % versus 25.1 ± 7.04 %, 12.5 ± 7.04 %, respectively). No significant interaction existed between the factors, nor was BE significantly different from control (Table 2 and Figure 1).

Within the 30 day observation period, a total of 224 of the 314 gilts expressed their first estrus. Of those gilts, a significantly higher ($P < 0.0001$) percentage of PG-600 + BE gilts responded than did BE and control gilts. The percentage of PG-600 gilts responding was significantly higher than control gilts, but not significantly lower than PG-600 + BE gilts or higher than BE gilts. The 90 gilts that did not exhibit estrus within 30 days were excluded from the data set which compared the number of days to first estrus. Treatment with PG-600 was the only factor affecting puberty. PG-600 significantly reduced ($P < 0.0001$) the mean days to first estrus (7.78 ± 0.959 and 6.59 ± 0.917 days for PG-600 and PG-600 + BE, respectively) compared to the BE and control treatments (12.24 ± 1.10 and 16.15 ± 1.23 days, respectively). There was no difference in BE verses control, and there was no significant interaction between the factors of PG-600 and BE (Table 3 and Figure 2).

The absence of a significant boar effect is interesting, as previous research has shown that boar exposure has a significant effect on puberty when initiated at 160 days of age. Perhaps other factors influencing age of puberty diminished the effect of boar exposure.

Elevated ambient temperatures (33.3°) from 150 to 230 days of age can significantly delay puberty in gilts (Flowers et al., 1989). While a cooling system (sprinklers) was in place and used on the animals, it is possible that temperature played a role in delayed puberty or lack of estrus expression. Daily maximum, minimum and average air temperatures were gathered from the research weather station in Brunswick, MO, 41.84 km from the farm (Table 4). During the first replicate, gilts experienced five days of maximum temperatures ≥ 33.3°C, and many days had maximum temperatures a few degrees below 33.3°C (Figure 3). During the second replicate, gilts experienced 20 days of temperatures ≥ 33.3°C (Figure 4). Many of the high-temperature days coincided with the time of anticipated second estrus for both replicates.

A high libido boar is more effective in stimulating gilts (Hughes 1994; Zimmerman et al., 1997). For this study, the boar was allowed to nudge and move around the gilts, but for the prevention of leg injuries, was not allowed to mount. This interference may have negated boar contact stimuli to some degree. The high temperatures may have affected the activity level of the boar, as during the estrus detection period, it appeared that the boar was less active in the July replicate than the June replicate, though not to a significant degree ($P > 0.05$). The efficacy of boar exposure can be diminished during the summer months (Hemsworth et al., 1988). But, increasing frequency and duration of boar exposure can overcome the summer depression

(Philip and Hughes 1995). Paterson et al. (1989b) reported no significant difference between gilt groups exposed to either five or seven days of 30 min of daily physical boar contact in spring months. However, the interval to puberty was significantly shorter for the seven-day exposure group compared to the five-day exposure group during the fall months. Under the conditions of the present study, 10 min of full physical boar contact five days a week may have been insufficient to negate seasonal infertility.

Exposure of gilts to the same boar may have caused habituation in the present study. In an experiment by Brooks and Cole (1969), gilts receiving exposure from a rotating pair of litter brothers responded earlier and in a more synchronous manner than gilts receiving exposure from only one boar. In the present study, because stimulation was in a separate facility from the breeding herd, only one boar was available.

PG-600 and PG-600 + BE were not significantly different ($P > 0.05$) from each other in the response to treatment within seven and 30 days, the interval from treatment to estrus, or the proportion recycling. This is consistent with an experiment by Paterson and Lindsay (1981), which reported no significant treatment effect in initial estrus response in gilts treated with PG-600 and PG-600 + BE gilts (83 % expressing first estrus in both treatment groups). Paterson and Lindsay (1981) provided continuous fence-line boar exposure by penning gilts adjacent to mature boars. The PG-600 group was housed in a separate barn, isolated from boars.

Eighty-five of the 146 gilts in estrus within seven days returned to a normal estrus 18 to 23 days later. Although the BE and control groups had fewer gilts respond within seven days, a larger proportion ($P=0.0035$) recycled within 18 to 23 days; (100 ± 9.74 % of BE versus 78 ± 9.74 % control and, 55.8 ± 9.11 % and 50 ± 9.11 % for PG-600 and

PG-600 + BE, respectively). There was no interaction between PG-600 and BE (Table 5 and Figures 5 and 6). The gilts initially responding to BE and control treatments were likely the most physiologically mature of their group; therefore, the continuation of a normal cycle in these gilts was expected. The additional stimuli provided by boar exposure did not improve the incidence of a normal second estrus. Paterson and Lindsay (1981) reported that the continuation of boar exposure enhanced the proportion of gilts maintaining cyclic activity (82 % vs. 58 % for PG-600 + BE and PG-600, respectively). This did not appear to be the case under the conditions of this study. More similar to the present study, Paterson and Martin (1981) did not report a significant difference between PG-600 and PG-600 + BE groups for second estrus response, although numerically, PG-600 + BE had a higher number of gilts expressing a second estrus. However, in the present study, the PG-600 group had a numerically higher number expressing a second estrus.

Two minutes of full boar contact can induce puberty in gilts, but it is not effective for a rapid response (Paterson et al., 1989a). In the present study, the two minutes of fence-line contact provided to PG-600 gilts may have masked the benefit of BE, though the lower PG-600 + BE gilt response is more likely due to a diminished boar effect.

A normal distribution was seen in initial gilt weight (Figure 7). Half of control gilts showed estrus within 30 days regardless of initial weight. PG-600 and BE gilts with heavier initial weights had a higher probability of coming into estrus. Heavier gilts in the PG-600 + BE group had a lower probability of cycling (Figure 8) but only six gilts represent the downward trend. A similar trend was seen for initial age at treatment (Figure 9). The distribution of age represents six birth groups (Figure 10). In general, age at puberty decreases as an increase in weight and age is seen (Hughes and Varley, 1980). The six gilts in the PG-600 + BE group that did not express estrus were between 109 and 129 kg and 187 and 191 days of age. The reason for the lack of response from these gilts is not known. A normal distribution in initial backfat thickness was seen (Figure 11). A large proportion of PG-600 and PG-600 + BE gilts showed estrus within 30 days regardless of backfat thickness. BE gilts with thicker initial backfat measurements had a higher probability of coming into estrus (Figure 12). Because the increase in the slope for control gilts was not significant, approximately half of the control gilts showed estrus. Due to the process of learning how to use the Lean-Meater, some gilts in the first replicate were measured with the switch turned to measure the first layer of fat, instead of at the setting to measure the second layer of fat. Because of this error, it is believed that the second backfat measurements are likely to be more representative of gilt treatment response. Distribution of backfat thickness measured seven days later was similar to the distribution of the first measurements (Figure 13). Probabilities reported were similar to the initial backfat probabilities, but the slope for BE gilts was not significant. Approximately 60 % of BE gilts showed estrus within 30 days regardless of backfat thickness (Figure 14). For the present study, neither weight, age nor backfat thickness were reliable indices for puberty attainment.

Eliasson et al. (1991), reported a negative correlation between backfat thickness at 90 kg and age at puberty. The majority of gilts in the present study were initially heavier than 90 kg. Gaughan et al. (1997), reported a negative correlation between backfat thickness at 140 days of age and age at puberty. All gilts in the present study were older than 140 days. Rozeboom et al. (1995), reported little influence of backfat thickness on puberty attainment. Young et al. (1990), observed that in environmentally stimulated gilts, weight and backfat thickness were not related to age at puberty. Rozeboom et al. (1995), reported a considerable variation in age, weight and backfat thickness at puberty in gilts receiving boar exposure at 120 days of age. Patterson et al. (2002b), also reported a large variation in weight and backfat at the onset of puberty in gilts receiving boar exposure at 120 days of age. While relationships between age, weight and backfat thickness have been reported, it is more likely that they are permissive, and do not truly control the onset of puberty. The metabolic state of the animal may be what ultimately determines the onset of puberty (Rozeboom et al., 1995).

Farrowing rate was not significantly different (P=0.8988) among treatment groups, averaging 90.9 % (Table 6). Litter size among treatment groups for pigs born alive (9.98, P=0.4636), pigs born dead (0.56, P=0.3881) and total pigs born (10.53, P=0.5280) were not significantly different (Table 7). It is interesting that no significant variation was observed, as the gilts that responded to treatment within 30 days would not have been bred at pubertal estrus, while some of the gilts that did not respond to treatment may have been bred at pubertal estrus.

Mating gilts at pubertal estrus has been shown to increase embryonic mortality (Warnick et al., 1951). An experiment by Dial and Bevier (1986) reported that gilts mated at pubertal estrus produced 1 to 1.5 fewer pigs born alive in the first litter than gilts mated at second estrus. Young et al. (1990), reported gilts bred at second estrus had 1.3 more pigs born alive compared to gilts bred at pubertal estrus after four litters. Iwamura et al. (1998), reported a decrease in litter size for PG-600-treated gilts mated at pubertal estrus. However, Britt et al. (1989), and Burnett et al. (1988), reported no difference between PG-600 treatment and controls on farrowing rate and litter size when gilts were mated at pubertal estrus. For the present study, it is uncertain at what estrus gilts were bred as gilts responding to treatment were not bred at that time, and estrus activity of all gilts was not monitored while gilts were in the acclimation barn. Gilts were moved to the breeding and gestation barns and mated randomly, regardless of treatment (Figure 15).

Implications

The greatest response was to PG-600, suggesting it is a useful tool for application in commercial settings. Response to BE is dependent on many factors, and in this study was lower than expected. Addition of daily boar exposure to PG-600 did not result in an increase in proportion maintaining cycles and may not be warranted. Farrowing rate and litter size were not affected by treatment. Under the conditions of this study, initial weight, backfat and age were not reliable indices to predict treatment response. Further study is needed for the effects of additional stimuli on the maintenance of cyclic activity after PG-600-induced estrus and for a better predictor of puberty.

Table 1. Legend for the recording of estrous behavior

I = investigates the boar
NS = vulva not swollen
SS = vulva slightly swollen
S = vulva swollen
NC = vulva no color
P = vulva pink/red
E = ear popping
Suspect = acts like in estrus (I S P E), but may grunt excessively or move away when mounted
Δ = standing estrus

Table 2. Least-squares means for percentage of gilts expressing estrus within seven days

Treatment	No. of gilts	Percent Response
PG-600 + BE	63/78	80.8 ± 7.04^{a}
PG-600	54/78	69.4 ± 7.04^{a}
BE	19/78	25.1 ± 7.04^{b}
Control	10/80	12.5 ± 7.04^{b}

^{ab} Within a column, means without a common superscript letter differ ($P < 0.0001$)

Table 3. Least-squares means for percentage of gilts expressing estrus within 30 days and number of days from treatment to estrus

Treatment	No. of gilts	Percent Response	Response Days
PG-600 + BE	72/78	92.3 ± 5.77[a]	6.59 ± 0.917[a]
PG-600	64/78	83.4 ± 5.77[ab]	7.78 ± 0.959[a]
BE	49/78	64.3 ± 5.77[bc]	12.24 ± 1.10[b]
Control	39/80	48.7 ± 5.77[c]	16.15 ± 1.23[b]

[ab] Within a column, means without a common superscript letter differ ($P < 0.0001$)

Table 4. Temperature readings collected from Brunswick MO weather station.

Replicate One

	Month	Day	Year	Max Air Temp °C	Min Air Temp °C	Avg Air Temp °C
Gilts arrived	6	7	2006	30.9	15.4	23.5
Treatment initiated	6	8	2006	33.0	16.7	38.0
	6	9	2006	33.3	20.2	26.0
	6	10	2006	30.3	17.4	23.4
	6	11	2006	26.0	15.9	19.6
	6	12	2006	22.8	14.9	18.1
	6	13	2006	27.6	12.2	20.2
	6	14	2006	29.2	13.9	22.6
	6	15	2006	30.7	19.2	25.5
	6	16	2006	32.3	18.9	26.9
	6	17	2006	30.3	18.8	24.4
	6	18	2006	30.5	18.2	23.2
	6	19	2006	33.0	17.5	25.4
	6	20	2006	31.6	20.5	26.5
	6	21	2006	33.2	22.8	27.9
	6	22	2006	26.5	16.8	21.6
	6	23	2006	29.4	14.8	22.3
	6	24	2006	30.3	15.2	22.8
	6	25	2006	27.8	15.8	21.5
	6	26	2006	24.9	14.3	18.8
	6	27	2006	27.4	11.6	20.0
	6	28	2006	31.2	14.4	22.9
	6	29	2006	33.8	17.6	25.5
	6	30	2006	31.1	20.8	25.7
	7	1	2006	33.7	20.6	27.1
	7	2	2006	34.4	20.2	27.6
	7	3	2006	34.2	22.1	26.7
	7	4	2006	30.1	17.4	23.5
	7	5	2006	27.8	15.4	21.1
	7	6	2006	29.1	13.0	20.8

Table 4 continued

Replicate Two

	Month	Day	Year	Max Air Temp °C	Min Air Temp °C	Avg Air Temp °C
Gilts arrived	7	13	2006	35.7	19.8	27.1
Treatment initiated	7	14	2006	31.6	19.5	25.0
	7	15	2006	35.0	20.4	27.6
	7	16	2006	35.8	19.9	28.5
	7	17	2006	35.3	23.7	29.8
	7	18	2006	36.0	23.5	28.9
	7	19	2006	37.0	25.1	30.5
	7	20	2006	36.5	24.8	30.0
	7	21	2006	25.0	18.0	21.9
	7	22	2006	28.2	17.0	22.0
	7	23	2006	31.9	15.6	23.5
	7	24	2006	33.2	17.0	25.0
	7	25	2006	33.9	21.4	27.5
	7	26	2006	33.6	24.9	28.5
	7	27	2006	30.9	21.1	24.7
	7	28	2006	34.9	19.1	26.5
	7	29	2006	36.1	22.8	29.0
	7	30	2006	36.5	22.1	29.5
	7	31	2006	36.7	25.5	30.4
	8	1	2006	36.8	25.4	30.5
	8	2	2006	35.9	21.6	29.5
	8	3	2006	30.7	18.8	24.2
	8	4	2006	32.6	15.9	24.2
	8	5	2006	34.2	19.9	26.5
	8	6	2006	39.0	22.2	29.3
	8	7	2006	33.9	22.6	27.1
	8	8	2006	33.7	23.1	26.9
	8	9	2006	38.8	22.4	29.5
	8	10	2006	33.0	24.1	27.9
	8	11	2006	31.2	20.4	25.2

Table 5. Least-squares means for percentage of gilts expressing estrus within seven days and a normal second estrus within 18 to 23 days later

Treatment	No. of gilts	Percent Response
PG-600 + BE	31/63	50.0 ± 9.11^{a}
PG-600	27/54	55.8 ± 9.11^{a}
BE	19/19	100.0 ± 9.74^{b}
Control	8/10	78.0 ± 9.47^{ab}

[ab] Within a column, means without a common superscript letter differ (P=0.0035)

Table 6. Least-squares means for proportion of bred gilts farrowing

Treatment	Farrowing Rate (%)[a]
PG-600 + BE	90.0 ± 5.82
PG-600	91.1 ± 5.82
BE	94.2 ± 5.82
Control	88.3 ± 5.44

[a] P = 0.8988

Table 7. Least-squares means litter size characteristics

Treatment	Pigs born alive[a]	Pigs born dead[b]	Total pigs born[c]
PG-600 + BE	9.90 ± 0.352	0.44 ± 0.161	10.38 ± 0.355
PG-600	9.57 ± 0.352	0.74 ± 0.161	10.19 ± 0.355
BE	10.30 ± 0.355	0.42 ± 0.162	10.72 ± 0.358
Control	10.18 ± 0.344	0.66 ± 0.157	10.84 ± 0.347

[a] P = 0.4636
[b] P = 0.3881
[c] P = 0.5280

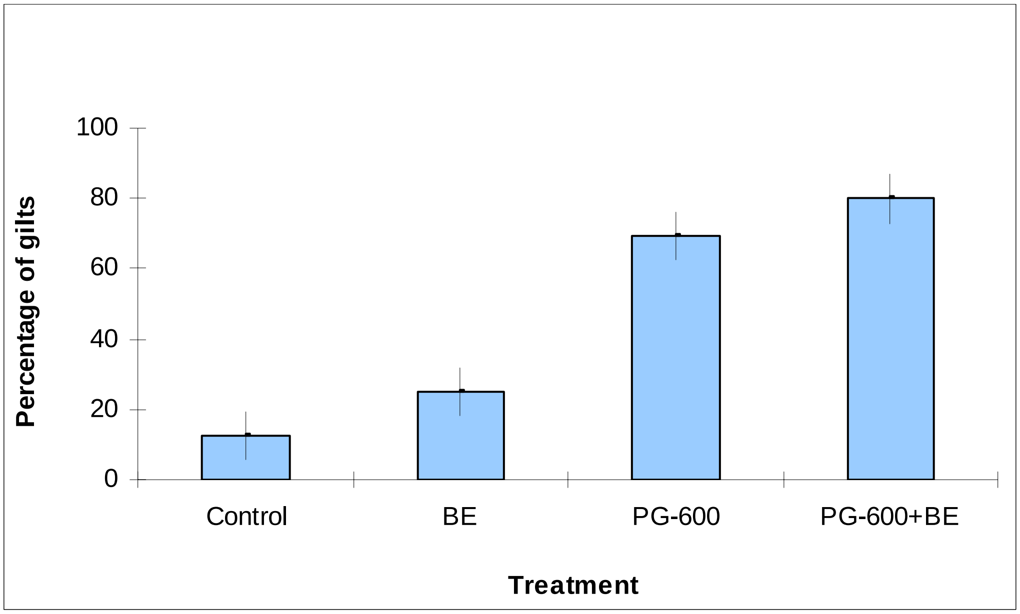

Figure 1. Percentage of gilts expressing estrus within seven days after initiation of treatment

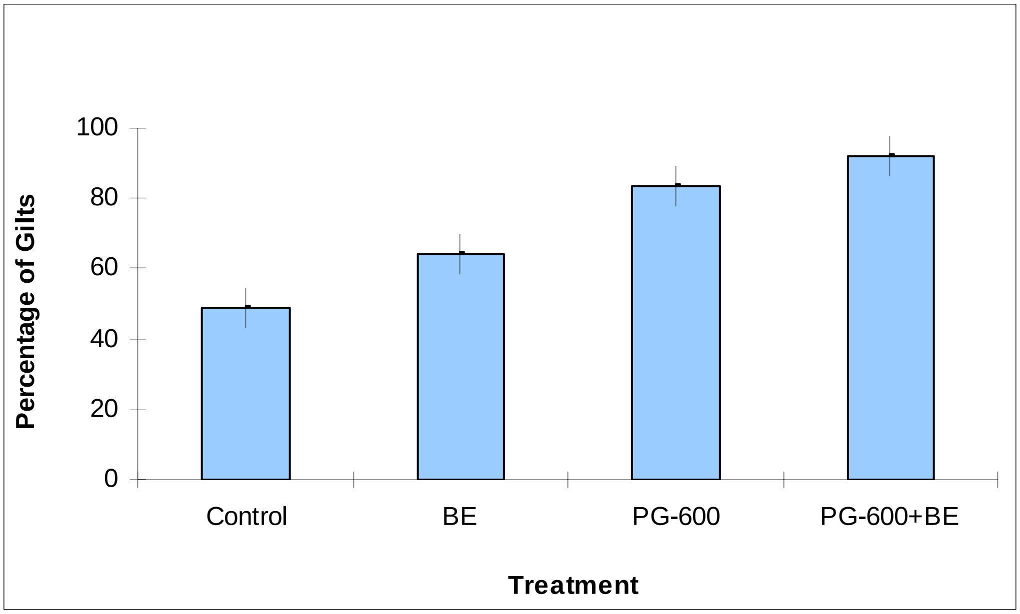

Figure 2. Percentage of gilts expressing estrus within 30 days after initiation of treatment

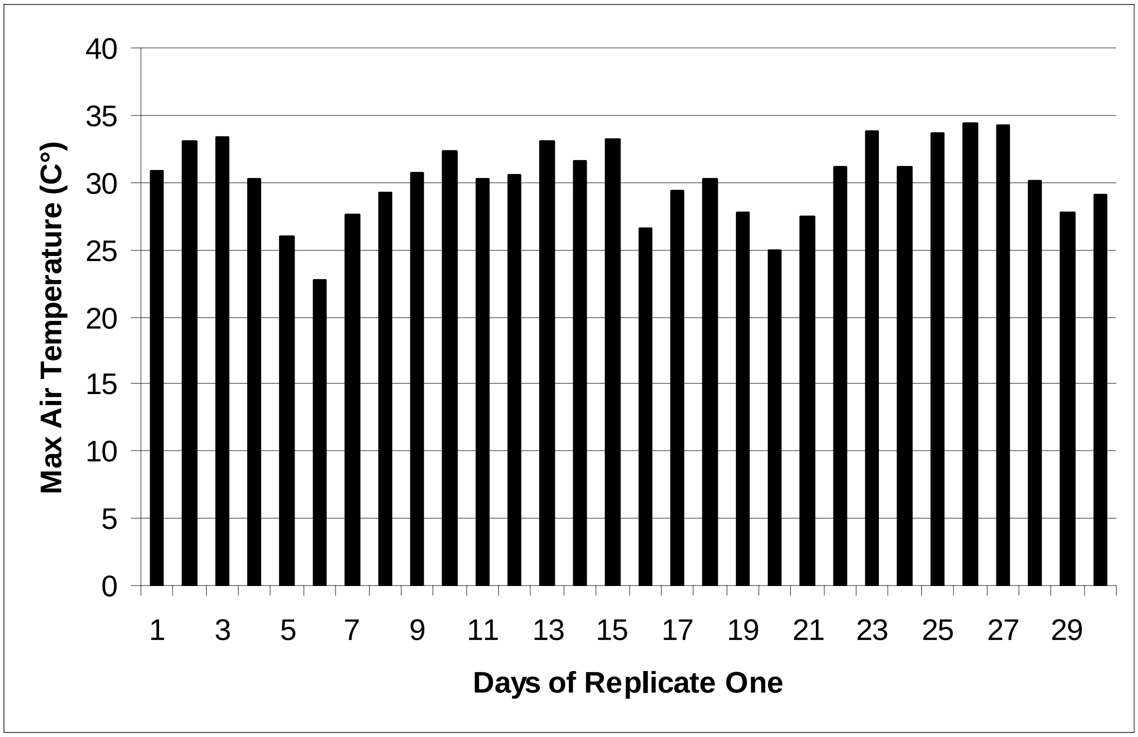

Figure 3. Temperature data for replicate one

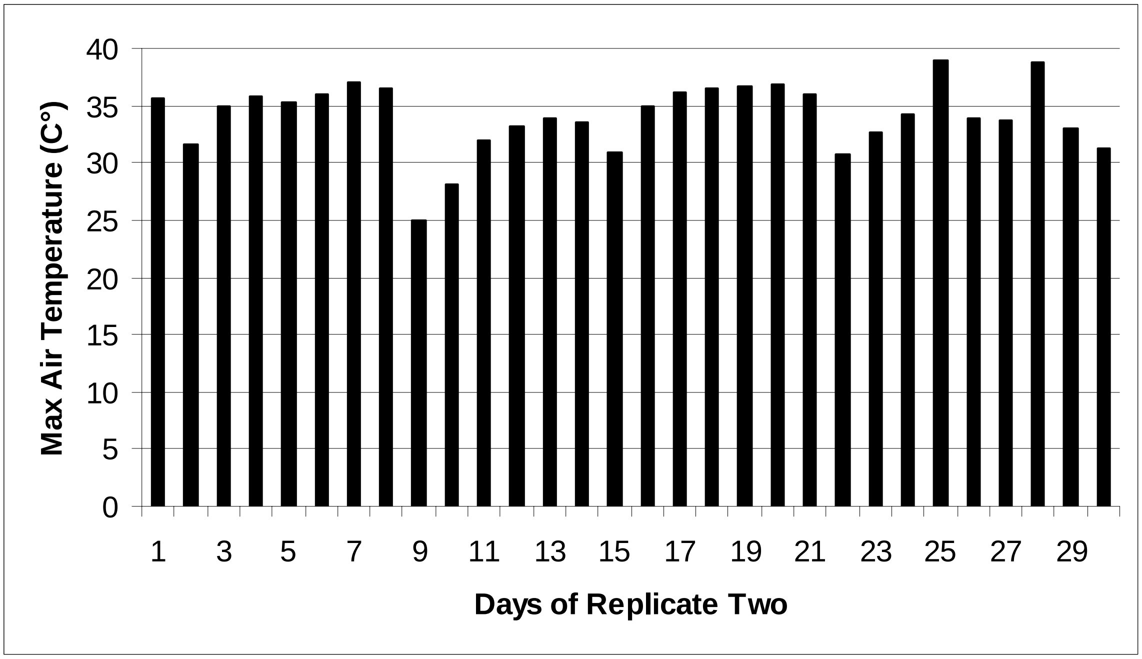

Figure 4. Temperature data for replicate two

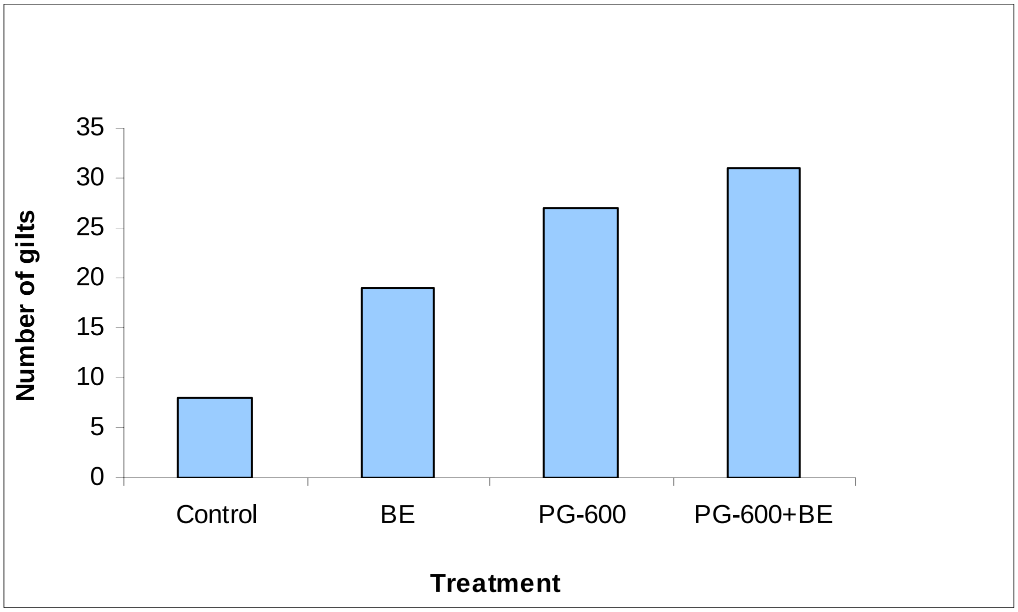

Figure 5. Number of gilts expressing estrus within seven days and that expressed a second estrus within 18 to 23 days later

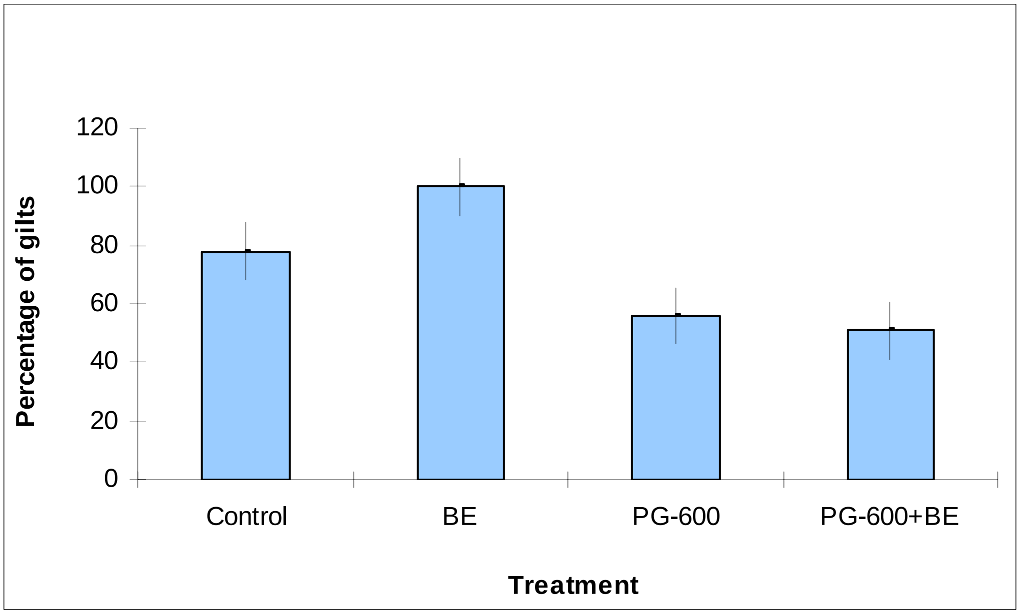

Figure 6. Percentage of gilts expressing estrus within seven days and that expressed a second estrus within 18 to 23 days later

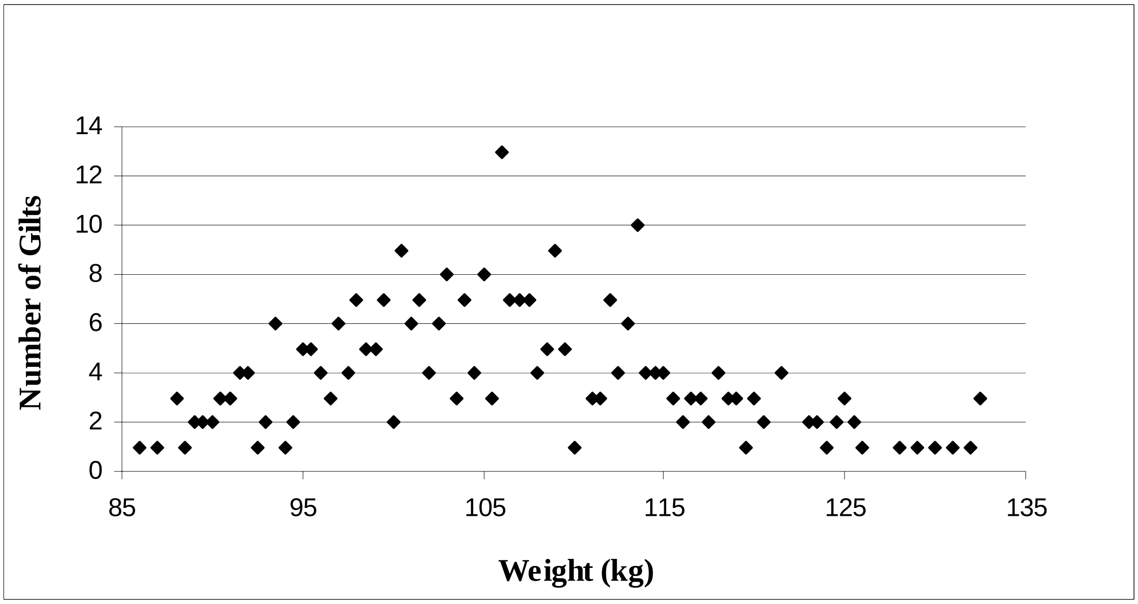

Figure 7. Distribution of gilts by initial weight

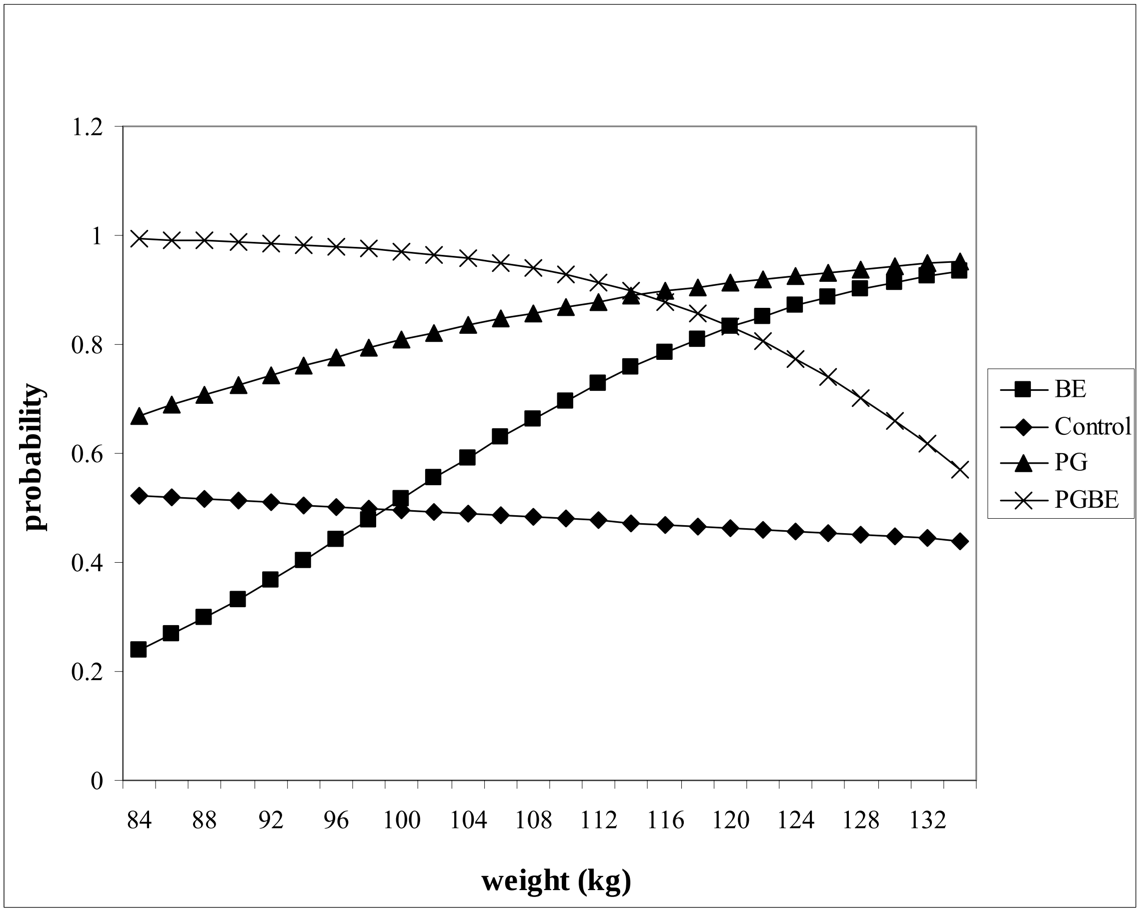

Figure 8. Probability of gilts expressing estrus within 30 days of treatment at initial weight, Pr > ChiSq: BE, 0.0095; Control, 0.7608; PG, 0.2137; PGBE, 0.0230

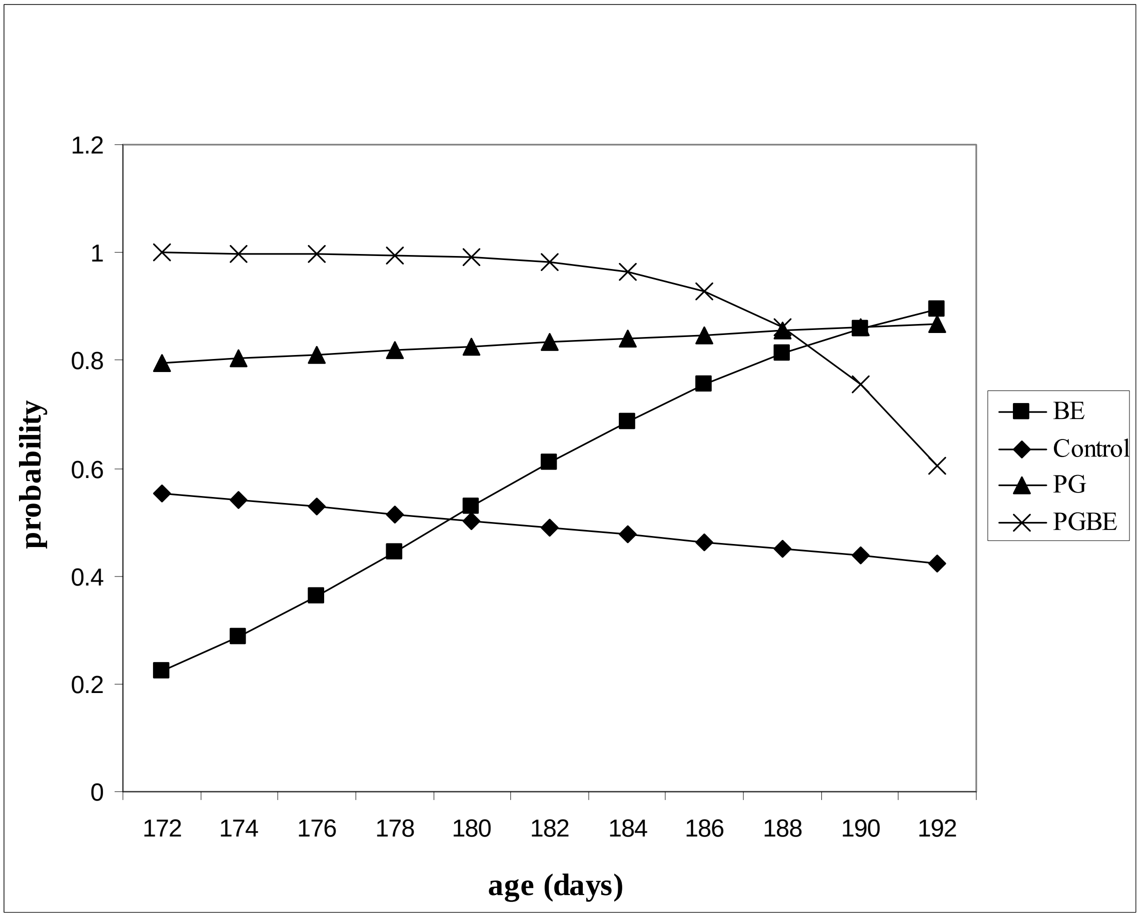

Figure 9. Probability of gilts expressing estrus within 30 days of treatment at initial age, Pr > ChiSq: BE, 0.0005; Control, 0.4871; PG, 0.5787; PGBE, 0.0146

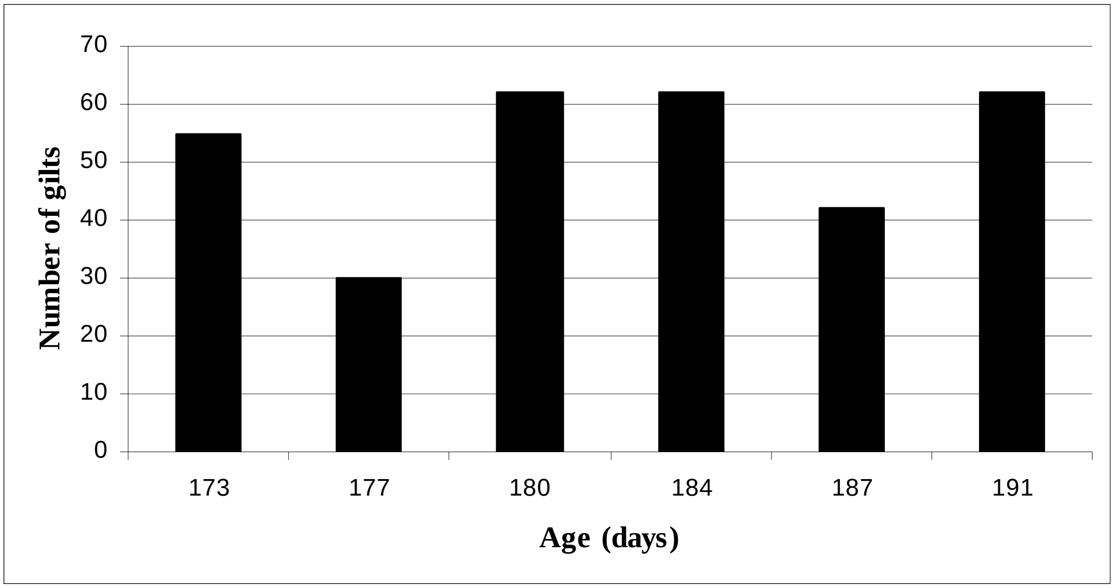

Figure 10. Distribution of gilts by initial age; birth week was all that was available

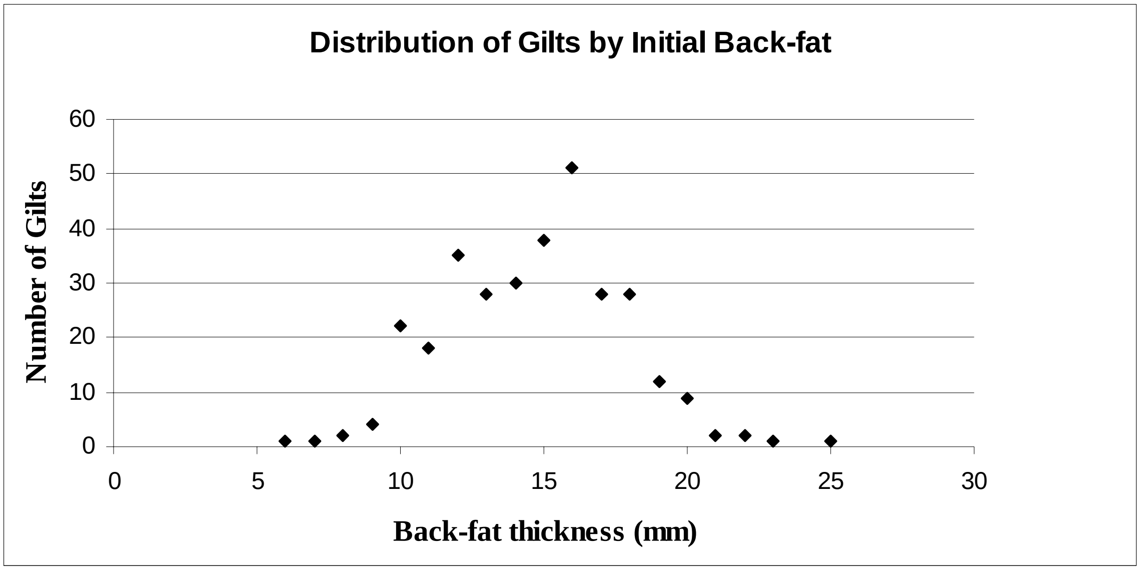

Figure 11. Distribution of gilts by initial backfat

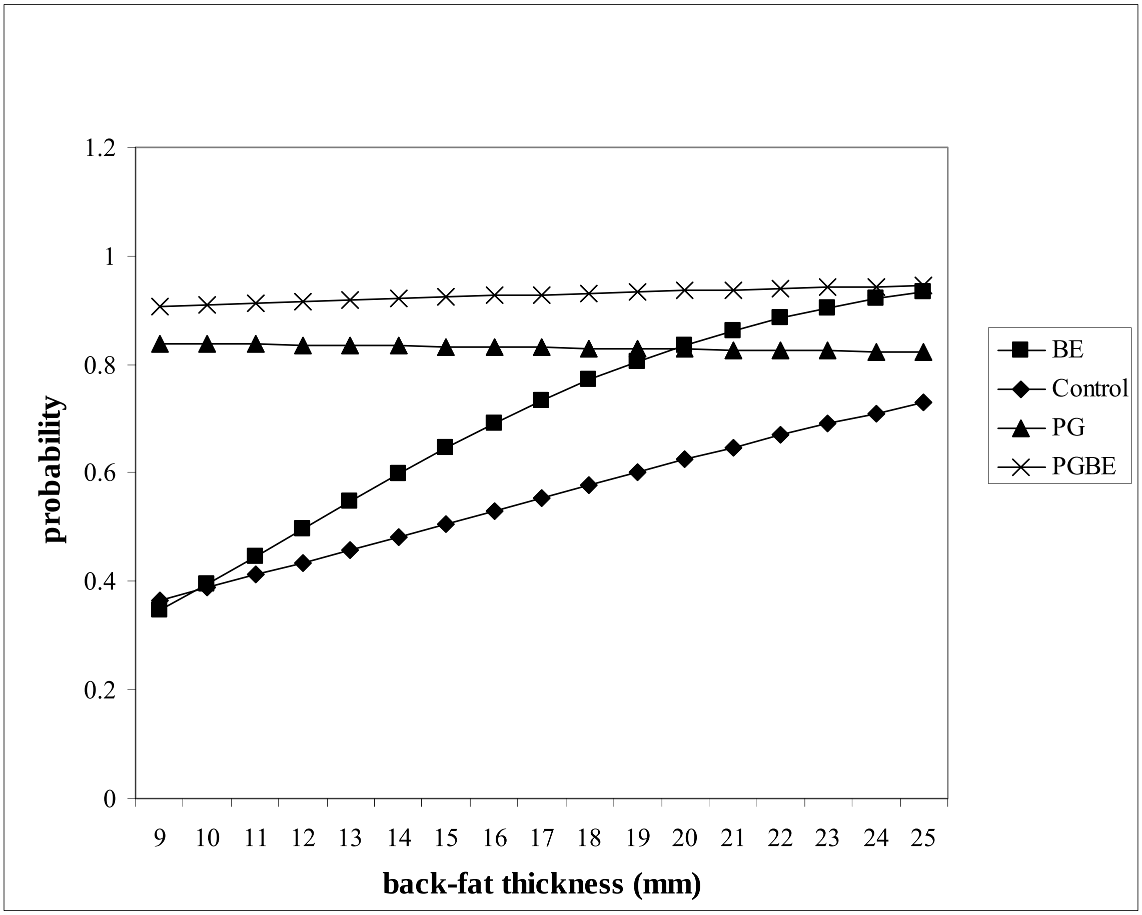

Figure 12. Probability of gilts expressing estrus within 30 days by initial backfat thickness, Pr > ChiSq: BE, 0.0338; Control, 0.2174; PG, 0.9383; PGBE, 0.7985

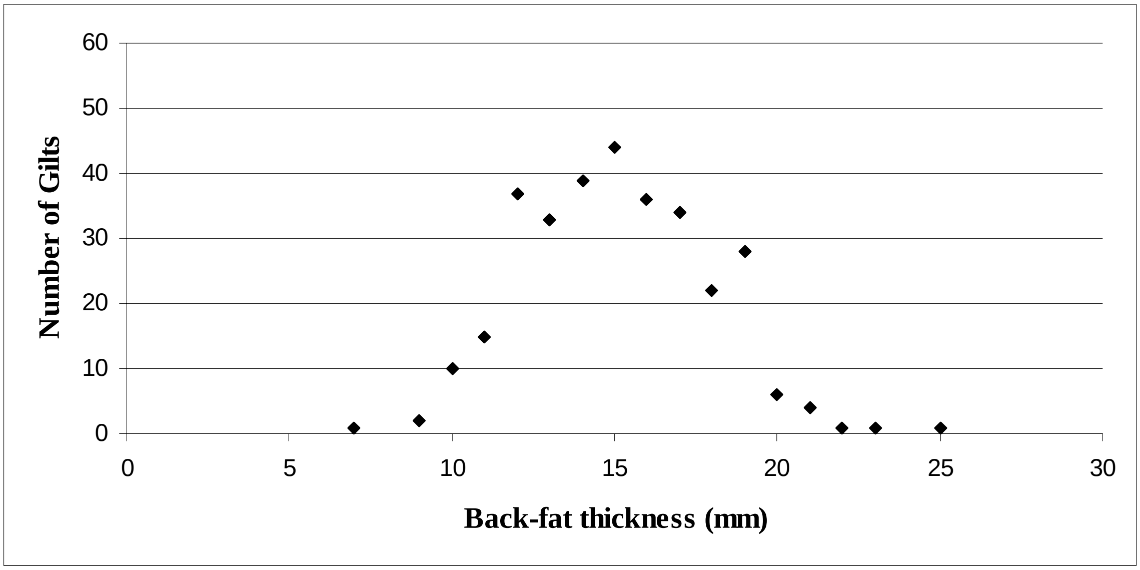

Figure 13. Distribution of gilts by second backfat measurement

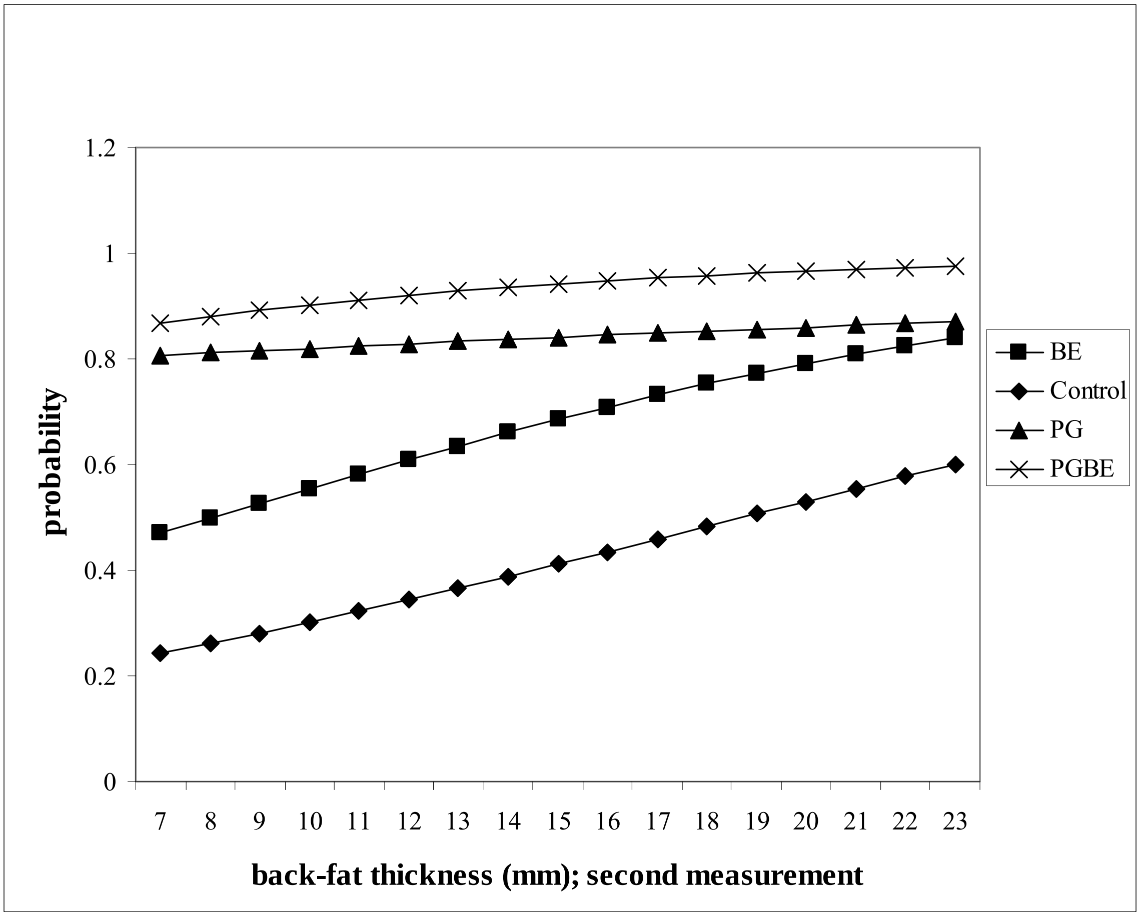

Figure 14. Probability of gilts expressing estrus within 30 days by second measurement of backfat thickness, Pr > ChiSq: BE, 0.2063; Control, 0.0939; PG, 0.8077; PGBE, 0.4256

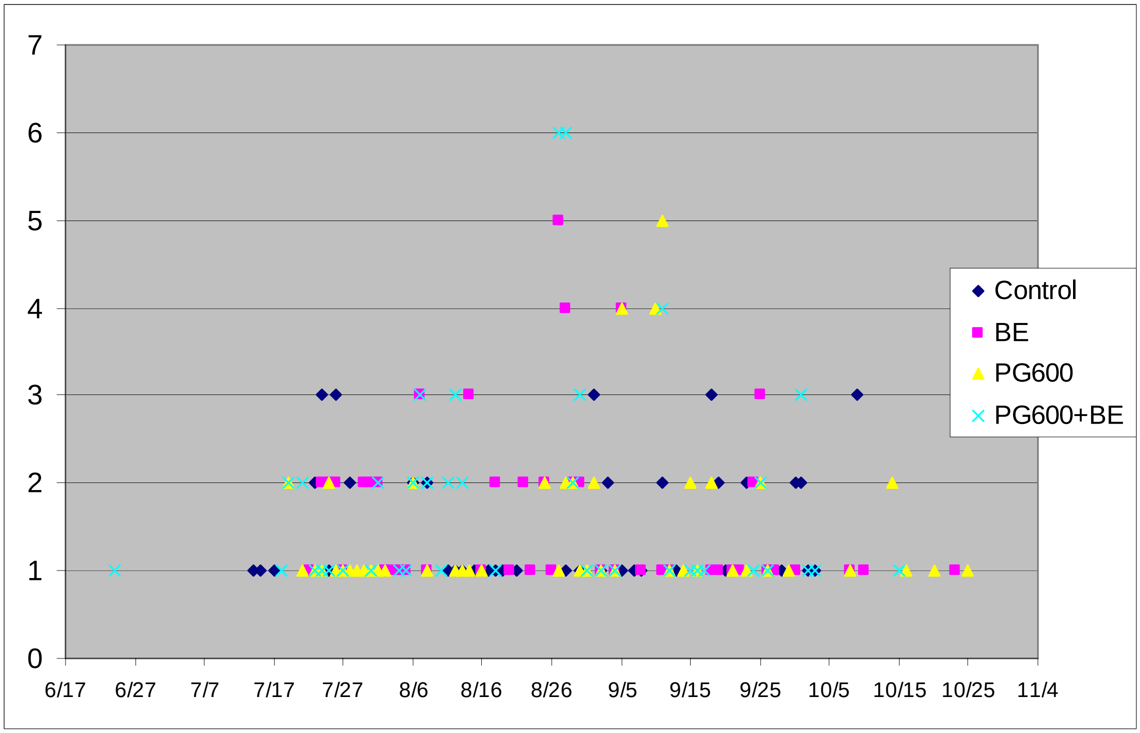

Figure 15. Distribution of mating dates by treatment

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