Current concepts in estrus synchronization in swine

C. T. Estill

College of Veterinary Medicine, Mississippi State University, Mississippi State 39762

Abstract

Several managerial and pharmacological methods are available for porcine estrus synchronization. Before implementing a method, producers must have a clear idea of the goal of estrus synchronization and a realistic expectation of the outcome. Induction of precocious puberty in gilts is perhaps the most economically favored estrus synchronization technique available to swine producers. Appropriately applied boar exposure and judicious use of gonadotropins are effective methods to improve productivity in breeding herds by reducing the number of days required for gilts to farrow their first litter. Proper management of sows during lactation and at weaning offers an excellent method to have synchronized estrus to facilitate rebreeding and the incorporation of an artificial insemination program. Gonadotropin treatment is also useful in sows at weaning to prevent delayed return to estrus associated with season and parity. Although not currently approved for use in the United States, the orally active progestogen "altrenogest" is effective for producing synchronization of estrous cycles in swine and would potentially facilitate synchronization of cycling sows and gilts. Alternative dose and duration protocols combined with $PGF_{2\alpha}$ may offer even more efficient and profitable uses of this hormone. Elective abortion or the establishment of pseudopregnancy followed by $PGF_{2\alpha}$- induced luteolysis will reliably synchronize estrus in gilts, but neither hormone is approved for this purpose. Research efforts to develop effective methods of estrus control will continue in order to support the increasingly mechanized and efficient swine enterprises of the future. Hormone-impregnated implants, pessaries, or biodegradable microspheres are potentially useful due to their improved labor efficiency compared with multiple-dosing protocols and are likely to be incorporated into future estrus synchronization programs.

Key Words: Estrus, Female Fertility, Gilts, Hormones, Sows, Synchronization

Introduction

Control of the porcine estrous cycle has been a goal of intensive scientific investigation for over 40 yr. Despite these efforts, swine producers remain much more limited with regard to availability of methods to alter estrous cycles and time of ovulation than their counterparts in the cattle industry. However, effective managerial and pharmacological methods exist to manipulate the estrous cycle of swine in specific reproductive categories. Although estrus synchronization is not feasible in all groups of breeding swine, there are instances in which swine producers are able to stimulate estrus in large numbers of females during a predetermined time period (Flowers, 1993). There are methods currently available to achieve this goal in both prepubertal and pubertal gilts as well as in weaned sows.

Despite the paucity of approved methods of estrus synchronization in swine, proper application of available protocols provides significant opportunity for increasing profitability of swine enterprises. Although the indications and implementation of estrus synchronization methods in swine are varied, they are all based either on controlling events leading to follicular maturation and ovulation or altering luteal lifespan.

Discussion

Induction of Estrus in Prepubertal Gilts

Influence of Boar Exposure on Puberty Attainment. Exposure to boars results in the induction of precocious puberty in gilts. With proper management of genetics, nutrition, environment (Christenson, 1981; Diekman, 1988) and boar exposure (see Zimmerman, 1988 for review), gilts can routinely be induced into puberty during the 5th mo of life. In contrast, if gilts are raised with growing-finishing hogs, only about 1% will have reached puberty by the time they reach 100 to 104 kg at approximately 7 mo of age (see Aherne, 1988 for review). Fortunately, most prepubertal gilts older than 140 d will respond to boar exposure (Flowers, 1993). The time interval from relocation and boar exposure to puberty is reduced as age increases from 160 to 200 d (11.35 vs 5.94 d, respectively, from boar exposure to estrus; Eastham et al., 1986). However, delaying the application of the pubertal stimuli (boar influence) beyond a mean gilt age of 160 d resulted in gilts being older and heavier at puberty and did not have any positive effect on early reproductive performance (Eastham et al., 1986). Therefore, in order to achieve maximum benefit, boar exposure should be initiated by 160 d of age. In general, exposure to a mature boar (≤ 11 mo) for 5 to 30 min/d (Caton et al., 1986; Paterson et al., 1989) can be expected to result in rapid induction of puberty in gilts. The exact amount of boar exposure required to stimulate onset of puberty in prepubertal gilts may vary throughout the year, with more exposure needed in the summer and less in the spring (Paterson et al., 1989). Experimental evidence suggests that olfactory stimuli (16-androstene steroids) from the boar and the simultaneous exposure to tactile and possibly visual and auditory cues are required to stimulate the onset of puberty in gilts (Pearce and Hughes, 1987). A higher proportion of gilts can be expected to reach puberty in response to a boar when daily, full, physical contact is permitted, compared with fence-line contact alone (Karlbom, 1982; Pearce and Paterson, 1992). Therefore, in some situations, fence-line interaction between gilts and boars may not be sufficient to stimulate precocious puberty and direct contact is required for maximum benefit.

Traditionally, gilts have not been bred on their pubertal estrus, but rather at the second or third estrus, because it was believed that gilts bred at puberty generally produced 1 to 1.5 fewer pigs in their first litter than gilts bred at second estrus (Dial and BeVier, 1986). Experimental evidence does not support delaying breeding after pubertal estrus; there is no productive advantage, and there may be an economic disadvantage associated with this practice (Neto, 1992; Neto and Oliveira, 1994).

Pharmacological Induction of Estrus in Prepubertal Gilts. The only approved pharmacological agent for inducing precocious puberty and fertile estrus in swine is P.G. 600 (Intervet America, Millsboro, DE.). Each dose contains 400 IU of eCG and 200 IU of hCG. When gilts aged 5.5 to 7.5 mo were treated with P.G. 600 at the time they were relocated from a finishing floor to breeding pens, 57.5% were in estrus within 7 d, compared with 40.9% of untreated gilts (Britt et al., 1989). An additional advantage of puberty induction with P.G. 600 is that, if more gilts are in estrus than are required for a given period, unmated animals will remain well synchronized at the subsequent estrus, and animal availability for future breeding can be predicted (Schilling and Cerne, 1972). Prepubertal gilts must be of sufficient age and weight to ensure profitable use of combination gonadotropin therapy (Burnett and Walker, 1988; Britt et al., 1989; Karalus et al., 1990). Gilts should be at least 5.5 mo of age and weigh a minimum of 85 kg when P.G. 600 is used (manufacturer's recommendation). Even though gilts may respond to P.G. 600 as early as 120 to 130 d of age, those treated at this age are not likely to continue to cycle after the P.G. 600-induced estrus and if bred at the induced estrus are unlikely to maintain a full-term pregnancy (Paterson et al., 1984; Burnett and Walker, 1988). In gilts of adequate age, boar exposure after the induced puberty promotes the continuation of fertile estrous cycles (Schilling and Cerne, 1972; Wentz et al., 1992). Overall, P.G. 600 is useful for inducing fertile estrus in prepubertal gilts and allows selection of fewer replacement gilts to fit a specified farrowing schedule, thereby permitting more market-weight animals to be sold for slaughter.

A less satisfactory method of inducing puberty involves the use of estrogenic steroids. Injection of estrogenic steroids induced an LH surge followed by ovulation in 60 to 68% of prepubertal gilts, but conception rates were only 33 to 67% (Kirkwood and Thacker, 1988). Estradiol benzoate (**EB**), in doses ranging from 5 to 15 μg/kg body weight divided over 3 d, resulted in 77.5% of gilts ovulating within 10 d regardless of dose, provided that treatment commenced at $\leq$ 140 d of age (Yang et al., 1987). Only 12 of 23 prepubertal gilts (174 ± 3 d of age) became pregnant following EB-induced estrus (Paterson et al., 1984). Because of inconsistent response and poor reproductive performance, the value of exogenous estrogens for inducing precocious puberty is limited.

Estrus and ovulation can be induced in prepubertal gilts (164 ±5 d of age) by the pulsatile administration of GnRH (over a 7- to 8-d period; Lutz et al., 1985). The GnRH treatment did not consistently result in continuation of cycles following the induced ovulation, indicating that puberty was not always associated with induced estrus (Lutz et al., 1985). Although use of this protocol can result in fertile estrus, practical application awaits development of less-labor-intensive drug delivery systems. The use of GnRH or a GnRH analogue may advance the time of ovulation in eCG-stimulated prepubertal gilts (Webel, 1978). Either 2 mg of GnRH or 20 μg of a GnRH analogue induced nearly complete ovulation if the interval between eCG injection and gonadotropin administration was 60 h or greater (Webel, 1978).

Synchronization of Estrus in Cyclic Sows and Gilts

The ability to control the time of estrus in cyclic swine would facilitate the introduction of gilts into the breeding herd as well as rebreeding of sows after weaning. The first attempts at pharmacological manipulation of the estrous cycle in cyclic swine involved prolonged administration of progestogens to inhibit the final stages of follicular development. Upon withdrawal of progestogen, follicles matured rapidly and ovulated within a predictable time interval. When 100 mg of progesterone in oil was injected daily into cyclic gilts on d 15 to 28 of an estrous cycle, estrus was suppressed for the duration of the treatment period (Ulberg et al., 1951). Estrus followed the last progesterone injection within 6 to 7 d and was associated with complete ovulation (absence of cystic follicular degeneration) (Ulberg et al., 1951).

One of the most successful compounds investigated for use in synchronizing estrus in cyclic gilts was methallibure (Gerrits and Johnson, 1965; Polge et al., 1968), which is a nonsteroidal compound that blocks gonadotropin release from the pituitary. When methallibure was fed for 19 d, fertile estrus was synchronously induced in a high proportion of animals within 5 to 8 d following removal from treatment (Gerrits and Johnson, 1965). Use of methallibure was halted and regulatory approvals withdrawn in many countries following reports of teratogenic effects (Webel, 1978).

In order to overcome the disadvantages of daily injections, several orally active progestational compounds have been examined for their utility in estrus control. Feeding 50 mg · gilt^{-1} · d^{-1} of 6-methyl-17α-hydroxyprogesterone acetate for 14 to 21 d resulted in 50% of treated animals in estrus during d 4 to 7 after withdrawal and 80% of treated animals ovulating (Dziuk, 1960). In another study, cycling gilts received 1.6 mg/d of 6-methyl-17α-hydroxyprogesterone acetate in feed for 24 d (Nellor, 1960). Estrus and follicular development were suppressed during treatment, and gilts were in fertile estrus an average of 4.4 d following discontinuation of the drug. Encouraging results with these compounds eventually led to the development of the most successfully used orally active progestogen, allyl trenbolone (Regu-mate, Hoechst Roussel Agri-Vet Co., Somerville, NJ). When Regu-mate was mixed with the daily ration or top-dressed onto the feed for 18 (Knight et al., 1976; Webel, 1978; Webel and Scheid, 1980) or 19 d (Davis et al., 1976) at the rate of 10 to 15 mg · gilt^{-1} · d^{-1}, mean time to estrus was 4.5 to 5.2 d (Davis et al., 1976; Knight et al., 1976; Webel and Scheid, 1980). Ovulation and fertility at the synchronized estruses were normal (Davis et al., 1976; Knight et al., 1976; Webel, 1978; Webel and Scheid, 1980). When 18-d treatment was compared with 14-d treatment, the synchronization of estrus was similar between treatment groups (Stevenson and Davis, 1982). Although 18-d treatment with Regu-mate (15 mg · gilt^{-1} · d^{-1}) improved estrus synchronization precision compared with14-d treatment, there was no advantage of the 18-d treatment for subsequent farrowing responses (Stevenson and Davis, 1982). The incidence of cystic follicles was low (Webel, 1978) compared with the incidence when another orally active progestogen (6-chloro Δ^6 17-acetoxy progesterone) was fed for 18 d (Wagner and Seerley, 1961). Regu-mate has also been used to synchronize estrus for timed insemination without estrus detection (Davis et al., 1985). When gilts were artificially inseminated on d 5, 6, and 7 after Regu-mate withdrawal, fertility and fecundity were equal to that of gilts that were tested for estrus and serviced naturally 12 and 24 h after the onset of estrus following Regu-mate treatment (Davis et al., 1985). In practice, Regu-mate, fed at the rate of 15 mg · gilt^{-1} · d^{-1} for 14 to 18 d, is an effective drug for synchronizing estrus in cycling swine. Treatment can be started on any day of the cycle. Conception rate, farrowing rate, and litter size is normal in Regu-mate-treated gilts. Underdosing Regu-mate (< 13 mg/d) may cause increased incidence of cystic follicles (Davis et al., 1979; Kraeling et al., 1981) and could explain why some producers have reported variable responses in the field (Kirkwood, 1999). Additionally, gilts that have not yet attained puberty before treatment will not reliably be induced into estrus after Regu-mate withdrawal (Kraeling et al., 1982). In the United States, Regu-mate is approved for use only in horses, although it is used widely in swine throughout Europe.

A potentially useful approach to providing progestogen exposure is via sustained-release implant. When randomly cyclic gilts were administered an implant containing 6 mg of norgestomet that was left in place for 18 d, five of six gilts were in estrus within 3 to 7 d after removal (Estill et al., 1997). Similarly, intravaginal placement of a progesterone-coated controlled internal drug-release device for 14 d caused 17 of 24 gilts to come into estrus between 3 and 5 d after removal (Peacock et al., 1992).

Another approach to synchronizing estrus in cyclic swine is to extend luteal lifespan, and then, when all animals have reached a stage at which they can be expected to respond to $PGF_{2\alpha}$, to induce luteolysis and synchronous return to estrus. Luteal function can be extended in cyclic swine by appropriately timed injections of hCG. When gilts were injected with 500 or 1,000 IU of hCG on d 12 of an estrous cycle, luteal function was extended to 31.0 and 61.4 d, respectively (Guthrie and Rexroad, 1981; Guthrie and Bolt, 1983).

A second method to extend luteal function is by daily injection of EB (5 mg/d) on d 11 to 15 of the cycle (Geisert et al., 1987). The rationale for estrogen treatment is that estradiol of blastocyst origin (Perry et al., 1973; Gadsby et al., 1980) is the primary signal for maternal recognition of pregnancy and luteal maintenance (Perry et al., 1973; Bazer and Thatcher, 1977). Gilts that have been rendered pseudopregnant by administration of EB maintain luteal function for up to 300 d (Gardner et al., 1963; Greenwald and Wang, 1991). When $PGF_{2\alpha}$ was administered to pseudopregnant gilts 5 to 20 d following EB treatment, they returned to estrus in 4 to 6 d and were highly fertile (Guthrie, 1975). A preliminary study demonstrated that randomly cycling gilts can be rendered pseudopregnant by administration of estradiol implants left in place for 21 d (Estill et al., 1997). When injected with $PGF_{2\alpha}$ on the day of implant removal, five of six gilts were in estrus 5 to 7 d later (Estill et al., 1997).

Estrus and ovulation have been controlled by treatment with gonadotropins and $PGF_{2\alpha}$ (Guthrie and Polge, 1976a; Guthrie, 1979). The rationale is to induce the formation of accessory corpora lutea (**CL**) by administering hCG to delay estrus and ovulation and then inject $PGF_{2\alpha}$ to regress the accessory CL at a predetermined time (Guthrie and Polge, 1976a). Cycling sows were injected with 1,500 IU of eCG (d 0) followed by 750 IU of hCG 72 h later. On d 13 and 14, 10 mg of $PGF_{2\alpha}$, and 10 mg of $PGF_{2\alpha}$ plus 1,000 IU of eCG, respectively, were followed in 96 h by 500 IU of hCG. Estrus occurred 4 to 5 d following the second hCG injection in 83% of treated sows, and 75% of the estrual sows farrowed (Guthrie, 1979).

Gilts of Unknown Status

When the cyclic status of gilts is unknown, gonadotropin therapy can be used successfully for estrus synchronization (Rogozarski et al., 1996). Gilts should receive 14 to 18 d of Regu-mate treatment followed by gonadotropin (P.G. 600) (Kirkwood, 1999).

Synchronization of Estrus in Weaned Sows

Group weaning is the most successful method of estrus synchronization in adult sows and facilitates implementation of orderly production schedules. During lactation, follicular development is inhibited primarily by pig nursing activity.

When the litter is weaned, follicular development resumes and estrus follows (Palmer et al., 1965). Sows weaned following a 21-d lactation are normally in estrus within 4 to 6 d (Walton, 1986). However, the trend in recent years has been toward shorter lactation durations. The effects of reduced lactation length on subsequent reproductive performance have not been comprehensively evaluated, but data on weaning-to-estrus interval (**WEI**), first-service farrowing rates, and embryo numbers are available (Mabry et al., 1996; Marsteller et al., 1997). When parity-3 and older sows were weaned after lactations as short as 9 d, they recycled an average of 7 d or less, with first-service farrowing rates in excess of 70%. With parity-2 sows, lactation should be a minimum of 12 d if recycling within 7 d is expected. However, when parity-1 sows had lactation lengths less than 14 d, they required an average of 10 d or more to recycle (Mabry et al., 1996). In early-weaned (8 to 12 d lactation) sows, the WEI was increased by 1.8 d compared with controls (18 to 21 d lactation) (Marsteller et al., 1997). Early-weaned sows had reduced first-service conception rates (68 vs 87%) and fewer live embryos (10.4 vs 13) compared with conventionally weaned sows (Marsteller et al., 1997). In the future, gonadotropin treatment of early-weaned sows may be used to overcome some of the negative effects early weaning has on reproductive performance.

A study of records on 11,461 sows found that 78.4% were in estrus within 7 d after 17 to 30 d of lactation (Hurtgen et al., 1980). In a another large-scale investigation of the association between WEI and sow reproductive efficiency, litter size, farrowing rate, and pigs produced/mated female all decreased among sows mated during 7 to 10 d after weaning compared with sows mated during 3 to 6 or 11 to 14 d after weaning (Figures 1 and 2) (Wilson and Dewey, 1993). The cause of reduced reproductive efficiency in this group has not been conclusively determined, but it does not seem to be related to parity or breed (Vesseur et al., 1994). However, the duration of estrus and interval from onset of estrus to ovulation decrease with increasing WEI (Weitze et al., 1994; Kemp and Soede, 1996). Sows entering estrus six or more days after weaning tend to exhibit estrus for a short period (1 d), with no ovulations after standing estrus (Weitze et al., 1994). This has led to the suggestion that the reduced fertility is related to timing of insemination rather than to reduced reproductive capacity (Kemp and Soede, 1996). Although there are no differences in ovulation rates between sows with WEI ranging from 3 to 6 d, sows inseminated 0 to 24 h before ovulation had similar percentages of normal embryos regardless of WEI, but sows inseminated more than 24 h prior to ovulation or after ovulation had a lower percentage of normal embryos (Kemp and Soede, 1996). On farms where fixed-time insemination at 24 after first detection of estrus is practiced, there may be a significant number of sows inseminated at a less than ideal time when WEI exceeds 6 d (Kemp and Soede, 1996). Fertility reduction could be prevented by inseminating all sows twice with the first insemination within 12 h after onset of estrus (Weitze et al., 1994).

Although sows tend to be naturally synchronized to some degree when they are weaned simultaneously, postweaning treatment with a combination of eCG and hCG has been used to more closely synchronize estruses and ovulations in order to facilitate "appointment" insemination without relying on the detection of estrus (Christenson and Teague, 1975). When sows were treated with 1,000 IU of eCG on the morning following weaning and then with 500 IU of hCG 72 h after eCG and inseminated 24 h after the hCG injection, a pregnancy rate of 96% was achieved, which did not differ from that of control sows bred based on observed estrus (Christenson and Teague, 1975). Primiparous sows treated at weaning with P.G. 600 on the day of weaning had a shorter and more synchronous WEI, and a greater proportion of treated sows than of untreated sows were bred by 7 d (Kirkwood et al., 1998). There was no detrimental effect on farrowing rate, but litter size was reduced (Kirkwood et al., 1998). In a subsequent study, the day of injection (day of weaning or 1 d after weaning) did not affect the response of weaned sows to P.G. 600 (Kirkwood and Giebelhaus, 1998).

Female swine exhibit a seasonal breeding pattern that is characterized by a 20 to 30% decrease in the rate of early return to postweaning estrus from June to October compared with the remaining months of the year (Hurtgen, 1976; Te Brake, 1978). Prolonged WEI and persistent anestrus may occur when litters are weaned during the summer months (Hurtgen and Leman, 1979; Hurtgen et al., 1980; Britt et al., 1983; Cox et al., 1983a). Treatment with P.G. 600 will induce fertile estrus in summer-weaned sows 3 to 5 d following injection (Webster, 1978; Hurtgen and Leman, 1979; King et al., 1982). In sows whose litters were weaned in the summer and early fall after a 3- to 4-wk lactation, treatment with P.G. 600 at weaning significantly reduced days to postweaning estrus in first- and second-parity sows and postweaning anestrus in primiparous sows (Bates et al., 1991). Treatment of sows weaned in the summer months with this compound virtually eliminates the problem of seasonal anestrus (Hurtgen and Leman, 1979; Hurtgen, 1982). Alternatively, anestrous sows treated with P.G. 600 on d 11 to 12 or later after weaning can be expected to be in estrus within 3 to 8 d (Schilling and Cerne, 1972).

Reproductive performance in first-litter gilts and sows after weaning may be improved over that expected with P.G. 600 (Hühn et al., 1996). Greater precision is achieved in the events leading to ovulation by substituting GnRH or GnRH analogue for hCG when eCG is given 24 h after weaning. A dose of 50 μg of GnRH analogue is always required with first-litter gilts, but 25 μg is sufficient in higher-parity sows except during the summer months, when 50 μg is required (Hühn et al., 1996). Partial, or split, weaning can also be used effectively to reduce the WEI and improve synchrony in first-parity sows (Trujillo et al., 1992).

Estradiol benzoate has been used to synchronize postweaning estrus in sows (Lancaster et al., 1985). In sows injected with EB (10/kg BW) 2 d after weaning, WEI was significantly shortened and conception rate was not altered, but litter size was slightly reduced (Lancaster et al., 1985). Treatment on d 2 after weaning (following a 3- or 5-wk lactation) with 30 μg of EB/kg resulted in consistent estrus and ovulatory responses, although ovulation rates were below those expected in fertile, untreated sows (Edwards and Foxcroft, 1983). The timing of the preovulatory LH surge and subsequent rise in plasma progesterone concentrations suggest close synchrony of ovulation (Edwards and Foxcroft, 1983). When long-term anestrous sows (29 to 134 d postweaning) were treated with 500 µg of EB followed in 55 h by 50 µg of GnRH, all sows exhibited estrus within 2 to 3 d (Cox et al., 1983b). Ovulation occurred in eight of nine EB-treated sows, and pregnancy was established in all eight but only three of eight sows farrowed and litter size was small (5.3 pigs/sow) (Cox et al., 1983b). A subsequent study using higher doses of EB (10 µg/kg) or GnRH (200 µg) confirmed that fertility is severely impaired following either treatment (Dial et al., 1984). Although long-term anestrous sows may respond to EB or GnRH therapy, subsequent luteal function apparently is not normal and results in a reduced farrowing rate (Cox et al., 1983b).

Breed-and-Abort Synchronization

Induced abortion can be applied in a program designed to ensure availability of a specific number of estrual gilts during a predetermined 2- to 3-d period. Gilts can be bred at their pubertal estrus, which may be induced with P.G. 600, then aborted on d 14 to 90 of gestation, 4 to 6 d before the time when they are required to be available for rebreeding. Prostaglandin $F_{2\alpha}$ will induce abortion in pigs pregnant 12 to 90 d. Prior to d 12 of the estrous cycle or gestation, $PGF_{2\alpha}$ is not considered to be an effective luteolysin in swine (Diehl and Day, 1974; Hallford et al., 1975; Connor et al., 1976; Guthrie and Polge, 1976b; Lindloff et al., 1976; Krzymowski et al., 1978; Berghorn et al., 1989). The time between treatment and onset of abortion varies with stage of gestation but usually occurs 30 to 45 h after $PGF_{2\alpha}$ administration (Diehl and Day, 1974; Guthrie and Polge, 1978; Podany et al., 1982; Pressing et al., 1987). Ten milligrams of $PGF_{2\alpha}$ (Lutalyse, Pharmacia & Upjohn, Kalamazoo, MI) i.m. at 12-h intervals or 500 µg cloprostenol (Estrumate, Miles, Shawnee Mission, KS) provided a better luteolytic response than a single treatment with 20 mg of $PGF_{2\alpha}$ (Pressing et al., 1987). In gilts injected with cloprostenol 12 to 40 d after mating, abortion was reliably induced, and a very high proportion of gilts returned to estrus 4 to 7 d later (Guthrie and Polge, 1978). Insemination at the synchronized estrus resulted in normal pregnancy rates (Guthrie and Polge, 1978). Differences attributable to breed and season in the $PGF_{2\alpha}$ treatment to estrus interval of up to 1.3 and 1.8 d, respectively, have been observed, with the mean interval being longer in the fall than in the spring (Meeker et al., 1985).

Implications

Modern swine producers have several options when selecting methods to synchronize estrus in swine. To be successful, selection of the most appropriate method must be made after considering the age and weight of female swine as well as environmental and managerial factors. Therefore, expert guidance is recommended to maximize financial benefit and reproductive efficiency.

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Notes

1. Correspondence: phone: (662) 325-1122; fax: (662) 325-4548; E-mail: cestill@cvm.msstate.edu.

Table 1. Summary of drugs and procedures that are effective in altering estrus and ovulation in swine

Indication	Class of animal	Drug or procedure	Dose/frequency
Induction of puberty	Prepubertal gilts (>160 d of age)	Boar exposure	30 min/d
	Prepubertal gilts (>165 d of age and > 85 kg)	P.G. 600[a]	5 mL i.m.
Estrus synchronization	Cycling gilts	Regu-mate	15 mg/d for 14 d orally
	Cycling gilts or sows	Estradiol benzoate	5 mg/d on d 11 to 15 then
		Lutalyse or Estrumate	10 mg Lutalyse 500 µg Estrumate
	Cycling gilts	Permit breeding to fertile boars for 24 to 30 d, then PG 14 to 40 d later	10 mg Lutalyse twice, 12 h apart or 500 µg Estrumate
Group weaning	Lactating sows	After 14 to 28 d lactation	
Delayed\anestrus	Weaned sows	P.G. 600[a]	5 mL at or 1 d after weaning

[a] Approved for use specified in the United States; all others drugs are for experimental use only.

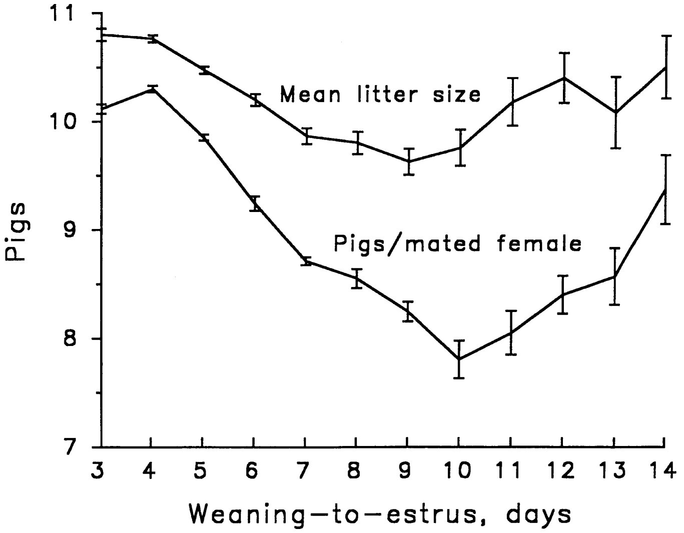

Figure 1. Mean litter size and pigs born per mated female (redrawn from Wilson and Dewey, 1993).

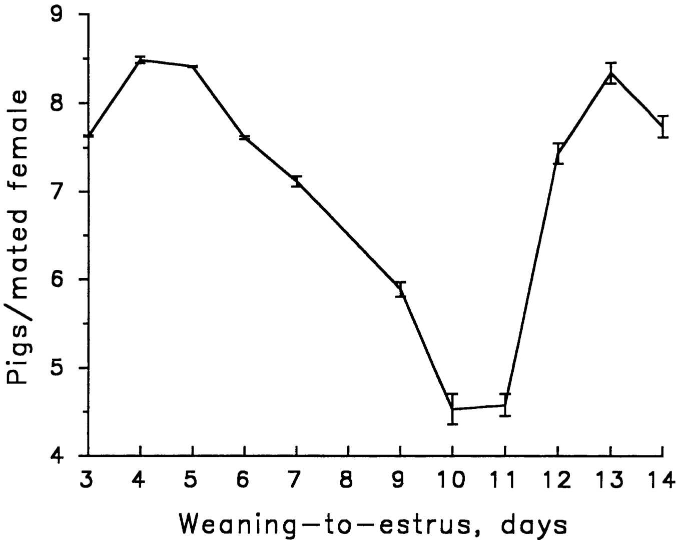

Figure 2. Pigs born per mated female (redrawn from Wilson and Dewey, 1993).