SWINE MANAGEMENT
TO INCREASE GILT REPRODUCTIVE EFFICIENCY¹,²

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ABSTRACT
Management practices to improve reproductive efficiency of the gilt will enable more efficient introduction of gilts into the breeding herd. In this paper, puberty and continuation of regular estrous cycles, ovulation rate and embryonic/fetal survival are the aspects of gilt reproductive efficiency to be considered. Within each of these reproductive areas, factors such as genetics, environment, nutrition, etc., are reviewed and general management practices are proposed. Because of the diversity of swine production systems, the proposed management practices to improve gilt reproductive performance must be considered and incorporated into individual herds on a trial basis.
(Key Words: Management, Puberty, Ovulation, Embryo Mortality, Gilts, Pigs.)

Introduction
A successful swine breeding unit is dependent upon the reproductive efficiency of the breeding herd. Swine producers must exercise a continuing effort to regulate the swine breeding unit if financial profit is to be a reality. Maintaining an optimum litter size at birth and increasing the overall efficiency of the breeding herd offer two good opportunities for assuring a productive swine unit. Because 30 to 40% of the sow herd is replaced by gilts each year, introduction of gilts into the breeding herd is an important aspect of herd productivity.

During the past 30 yr, many changes have occurred in the swine industry. There has been a dramatic change of the pig to the present-day lean, meat-type pig. In addition, pig production is shifting from small, nonconfined units to larger, total confinement units that may be foreign to the pig's natural habitat. This environmental change and the selection for the meat-type pig may have altered the behavioral patterns and physiology of gilts.

Management for Pubertal Development
Several factors that influence puberty and the continuation of regular estrous cycles in gilts have been identified. These include 1) detection of estrous, 2) genetics, 3) season of the year during sexual development, 4) confinement environment, 5) boar exposure, 6) nutrition and 7) disease. The influence of nutrition will not be discussed because the subject has recently been reviewed (Kirkwood and Aherne, 1985). It has been concluded that under normal conditions of feeding and management, nutrition will have a minimal influence on gilt development (Aherne and Kirkwood, 1985). These authors do suggest ad libitum feeding to the time of mating to maximize ovulation rate and to ensure against the

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Effects of subsequent poor management. It is not in the scope of this review to examine the influence of disease but to remind the reader that adequate disease control and management is necessary to allow normal gilt reproduction.

Detection of Estrus. The detection of estrous behavior in gilts is a critical factor for establishing puberty, estrous activity or breeding in gilts, and for the efficient operation of a swine breeding program. Detection of estrus is a simple technique. It involves placing the male and female pig in close proximity on a regular basis (once or twice daily) and observing behavioral changes in the female. Signoret and du Mesnil du Buisson (1961) and Signoret (1970) have described the reproductive behavioral patterns of the gilt but little scientific information is available on methods of detecting estrus, largely because of the wide range in confinement facilities, which makes detection procedures difficult to standardize. Moving a group of gilts once or twice daily to a large pen, in the presence of a mature boar, has proved to be a satisfactory method. In addition, during detection of estrus care must be taken to allow adequate time for individual gilts to seek out the boar and to respond to pressure applied to the back by the husbandryman.

Genetics. The influence of individual breeds and mating systems on age at puberty in swine reared under nonconfinement conditions has been reported (Robertson et al., 1951; Foote et al., 1956; Zimmerman et al., 1960). Foote et al. (1956) reported differences in age at puberty associated with mating types within the purebred and crossbred systems, as well as the effect of heterosis on reducing age at puberty in swine. Christenson and Ford (1979) determined age at puberty and continuation of regular estrous cycles in gilts of five breeds reared in total confinement. A total of 434 gilts of the Hampshire (89), Duroc (44), Yorkshire (119), Large White (114) and Swedish Landrace (68) breeds born in March and May were studied. The percentage of gilts showing regular estrous cycles in relation to chronological age (months) is presented in figure 1. Landrace gilts showed the highest estrous activity (number of gilts showing regular estrous cycles/number of gilts x 100) between 5 and 7 mo of age, and the percentage of Landrace gilts showing regular estrous cycles at 6 mo of age was higher (P<.01) than that of Hampshire, Large White, Yorkshire and Duroc gilts (69 vs 11, 4, 3, 0%, respectively). Therefore, introduction of early maturing breeds or crossbred lines may be advantageous for reducing age at first estrus in some herds. Estrous activity for the five breeds of gilts had reached a plateau at 8.5 mo of age, and the percentage of gilts showing regular estrous cycles was greater for Landrace, Large White, Hampshire and Duroc gilts than for Yorkshire gilts (78, 86, 71, 71 vs 56%, respectively). This plateau and other estrous data reported for gilts checked daily for estrus from 6 to 12 mo of age (Christenson and Ford, 1979) indicate that the percentage of gilts showing regular estrous activity will not increase significantly beyond 9 mo of age. Therefore, maintaining noncyclic gilts beyond 9 mo of age for replacement cannot be recommended.

Season. Climatic conditions (season), whether modified by confinement management or not, are factors that influence the process of sexual development in gilts. Wiggins et al. (1950) and Scanlon and Krishnamurthy (1974) have studied reproductive tract development in slaughter-weight gilts throughout the year. Data from these two reports indicate that gilts at market weight going to slaughter in late summer show less sexual development than at any other time of the year. Christenson (1981) reported that the percentage of gilts showing normal estrous cycles at 9 mo of age was less for gilts reaching breeding age during the summer than for gilts reaching breeding age during the winter. The effect was observed in both confinement and nonconfinement gilts. Collectively, these studies suggest that the summer

Figure 1. Estrous activity relative to age for gilts reared in confinement. Total number of gilts in parentheses.
climatic conditions cause a delay in sexual development of gilts. However, in a continuous farrowing production system, swine of most reproductive stages (i.e., pubertal development, breeding, early and late gestation) are adversely influenced by summer climatic conditions; therefore from a managerial standpoint, it is difficult to avoid the adverse influence of summer climatic conditions.

**Confinement Environment.** The shift from many small, nonconfined swine production units to fewer larger, total confinement units has increased both the reproductive problems in gilts and our awareness of such problems. Two studies have evaluated the influence of confinement on sexual development of gilts (Christenson, 1981; Rampacek et al., 1981). In Georgia, Rampacek et al. (1981) reported that at 8 mo of age, 22 of 29 (76%) nonconfined and 10 of 28 (36%) confined crossbred gilts had shown estrus. Christenson (1981) determined the percentage of gilts with regular estrous cycles from 2 to 9 mo of age in gilts reared in confinement or nonconfinement. The influence of confinement on gilts is shown in figure 2. Fewer gilts in confinement were cyclic at any age from 5 to 9 mo, and at 9 mo of age 71% of confinement-reared gilts were cyclic compared with 85% of nonconfinement-reared gilts.

Two aspects of confinement that may influence sexual development in gilts are social and building environments. The effects of social environment on reproductive behavior have been extensively studied in mice (Whitten, 1956; Bruce, 1959; Vandenbergh, 1974; Drickamer, 1975), but social factors appear to play a different role in the gilt (Mavrogenis and Robinson, 1976) than in the mouse. The expression of first estrus and regular estrous cycles in gilts has been reported to be altered by penning individually or in large groups. England and Spurr (1969) reported that gilts kept in confinement had a greater incidence (28 vs 16%) of silent estrus and irregular estrous cycles when housed in individual vs group pens (8 to 12 gilts/pen) from about 7 mo of age. Jensen et al. (1970) reported that individual tethering increased age at puberty by only 4 d, but the expression of estrus was less discernible in the tethered animals and the incidence of immature reproductive tracts at 10 to 12 mo of age was significantly greater for tethered than for non-tethered gilts (13/87 vs 0/87). Christenson (1984) reported that 57% of gilts penned in groups of three were cyclic at 9 mo of age as compared with 78, 80 and 81% of the gilts penned in groups of 9, 17 and 27, respectively. It may be concluded from these data that penning of gilts individually or in groups of three, before and during the breeding season, is detrimental when compared with penning of gilts in groups of 9 to 27. Likewise, the number of unmated gilts at 8 mo of age was greater in groups of more than 50 gilts than in groups of less than 50 (Cronin et al., 1983). Possible explanations may involve the complex social behavior of a large group of gilts and(or) the routine difficulty of the boar to detect, and the husbandryman to record, estrus and(or) mating events of gilts penned in a large group. Therefore, extremes in the number of gilts per pen should be avoided during the breeding period.

The social environment created by the density of animals (space allowance per pig) has also been suggested as a possible factor that influences puberty and regular estrous cycles in confinement-reared gilts. Ford and Teague (1978) studied age at first estrus in gilts (8 or 12 gilts per pen) reared from 3 to 8 mo of age in partially slatted pens, with controls having an initial floor space of .37 m²/pig and treated gilts being restricted to one-half the space allowed to controls. Pen size was increased by .09 m²/pig when the average weight per pig of each pen reached 34.1 kg and at every 13.6 kg increase thereafter. However, the number of gilts reaching puberty and average age at first estrus were not affected by crowding.

In terms of the environment created by confinement buildings, data have been reported on the influence of photoperiods on puberal development. Age at puberty has not differed for gilts reared under different lengths of daylight (Ntunde et al., 1979). Rearing gilts in

Figure 2. Percentage of cyclic gilts in confinement and nonconfinement relative to age.
confinement under complete darkness has been reported both to increase (Ntundu et al., 1979) and to decrease age at puberty (Dufour and Bernard, 1968). These data suggest that length of daylight may not be a major factor influencing age at puberty in confinement-reared gilts. Presently, there is little information available on the influence of confinement swine odor or ventilation on age at puberty in gilts. Because olfactory stimuli are involved in estrous behavior in gilts (Signoret and du Mesnil du Buisson, 1961), olfaction may be a factor as it relates to puberty in confinement-reared gilts (Malayer et al., 1985).

**Boar Exposure.** Exposure of gilts to a mature boar (12 mo of age or older) induces puberty at an earlier age in nonconfinement-reared gilts (Zimmerman et al., 1969, 1974; Brooks and Cole, 1970) and in confinement-reared gilts (Thompson and Savage, 1978; Kirkwood and Hughes, 1979; Cronin, 1983) than occurs for gilts isolated from boars. Zimmerman et al. (1974) and Brooks and Cole (1970) have reported that exposure to a mature boar enhances the synchrony of estrus among gilts, particularly if gilts are approaching pubertal age. But, puberty may be delayed if boar exposure is initiated when gilts are too young (Brooks and Cole, 1970).

**Management for Improved Ovulation Rate**

Gilts are polytocous animals, and the rate of ovulation varies considerably with 9 to 17 ova being the usual range. Genetics, nutrition and sexual age are the primary factors that have been shown to influence ovulation rate in gilts. For more in-depth reading on ovulation rate in swine, see Anderson and Melampy (1972) and Zimmerman (1972).

**Genetics.** Although breed differences in ovulation rate have not been investigated extensively, the available evidence indicates that some breeds show a consistently higher ovulation rate than others (Robertson et al., 1951; Rigor et al., 1963; Dyck, 1971; Clark et al., 1973; Young et al., 1976). Inbreeding usually reduces ovulation rate, whereas crossing purebred/inbred lines of gilts increases markedly the number of ova (Squiers et al., 1952). Further evidence of a genetic influence on ovulation rate is that the Nebraska Gene Pool population responded to selection for ovulation rate, and the trait was highly heritable (Zimmerman and Cunningham, 1975; Johnson et al., 1984). During 10 generations of mass selection for ovulation rate at second estrus, the response was .49 ova increase per generation. In gilts and sows of generations 9 and 10, line differences (select-control) ranged from 3.4 to 5 ova. However, even with this positive influence of selection, enhancing ovulation rate in gilts can be best realized through introduction of breeds or crossbred lines known for greater ovulation rate.

**Nutrition.** Plane of nutrition has been shown to affect ovulation rate significantly in swine. Robertson et al. (1951) and Self et al. (1955) reported that gilts provided continuous ad libitum feeding prior to second estrus produced greater numbers of ova than gilts restricted to about two-thirds of the ad libitum amount of feed. This response appears to be the result of increased energy intake per se (Zimmerman et al., 1958, 1960; Haines et al., 1959; Rigor et al., 1963).

Self et al. (1955) first reported that the gilt is responsive to short intervals of increased energy intake, i.e., “flushing.” A 3-wk period of ad libitum feeding of gilts just prior to ovulation produced greater numbers of ova than gilts restricted to about two-thirds of the ad libitum amount of feed. This response appears to be the result of increased energy intake per se (Zimmerman et al., 1958, 1960; Haines et al., 1959; Rigor et al., 1963).

**Sexual Age.** Physiological development is not completed with the attainment of puberty, as shown by increases in ovulation rate with successive estrous periods (Robertson et al., 1951; Warnick et al., 1951; Paterson and Lindsay, 1980). However, Dyck (1971) reported no increase in ovulation rate with sexual age. Results of several other studies (MacPherson et
al., 1977; Young and King, 1981; Knott et al., 1984) suggest that conception rates and number of pigs born increase for gilts mated at third vs first estrus. Kirkwood and Aherne (1985) concluded that in gilts reaching puberty at young ages (5 to 7 mo), ovulation rate will increase with each estrus period. In older gilts (8 to 10 mo) such as in the study of Dyck (1971), the influence of sexual age is much reduced. Therefore, in early maturing gilts (5 to 7 mo of age), some advantages of delaying mating to second and third estrus can be realized.

Management for Improved Embryonic/Fetal Survival

The studies of Hammond (1914) and Comer (1921, 1923) first directed attention to fertilization rate, conception rate and embryonic/fetal survival in domestic animals. A standard for these traits in swine was reported by Burger (1952). Fertilization rate in gilts is usually greater than 95%, and is essentially considered to be an all-or-none process. In swine, conception rate is used to signify those animals in which most ova are fertilized and pregnancy is established. The percentage of gilts mated that conceive varies considerably but in well-managed herds, a conception rate of 75% to 85% is not unusual. Embryonic/fetal mortality is a factor of considerable magnitude in the pig. At least 40% of the ova shed are not represented at parturition, and a majority (85%) of this loss occurs during the first third of gestation. Major influences on conception rate and embryonic/fetal survival include 1) the boar and its environment and 2) the gilt and its environment.

Boar. The boar constitutes an important element in the swine industry. In swine production, the boar breeds many females over a year's time while an individual female will conceive only one to two times during the same time period. Accordingly, a boar with suboptimal or low fertility would have a more critical economic impact in any swine enterprise than would a female with fertility problems.

General recommendations have been published for producers to follow during the selection and introduction of a new boar to the breeding herd (Levis et al., 1984). Factors such as genetics, age, health and soundness are generally in the forefront but swine producers need more complete information regarding selection of boars with superior reproductive ability. Studies of reproductive development in the boar (McFee and Eblen, 1967; Florcruz and Lapwood, 1978; Colenbrander et al., 1978; Allrich et al., 1982, 1983) and sexual behavior in the boar (Signoret, 1970; Winfield et al., 1981; Levis, 1984; Ford and Christenson, 1985) have begun to fill a void in our knowledge of boar reproduction.

Beyond physiological and behavioral factors that can influence boar fertility, external environmental factors have been shown to influence reproduction of the boar (Thibault et al., 1966; McNitt and First, 1970; Christenson et al., 1972; Wettermann et al., 1976; Wettermann and Desjardins, 1979; Cameron and Blackshaw, 1980). These researchers showed that reproductive fertility, as measured by semen quality of the boar, reduced pregnancy rates and increased embryonic mortality, is reduced for gilts and sows inseminated with semen from boars exposed to high environmental temperatures.

Gilt. The influence of nutrition on fertilization rate has been studied (Robertson et al., 1951; S elf et al., 1955; Haines et al., 1959) but has failed to show any significant effect. In contrast, embryonic survival may be affected adversely by ad libitum feeding (high energy intake). Continuous ad libitum feeding before breeding and during early gestation has been reported to cause increased embryonic mortality as compared with restricted feeding (Robertson et al., 1951; S elf et al., 1955; Haines et al., 1959; Gossett and Sorenson, 1959; Sorenson et al., 1961). Although the mechanisms by which high energy intake may increase embryonic mortality remain obscure, S elf et al. (1955) suggested that most of the increase in embryonic mortality was a result of high energy feeding during the early post-breeding period rather than the pre-breeding period. It must be pointed out that other researchers have failed to observe a detrimental influence on embryonic survival from high energy feeding during the early post-breeding period rather than the pre-breeding period. In spite of the uncertainty of ad libitum vs restricted feeding post-breeding, it is recommended that producers restrict feed intake after mating, primarily to reduce feed cost and possibly to improve embryonic survival in the gilt.

Results of several studies with gilts in environmental chambers have shown critical periods within the reproductive process which were influenced by increased environmental...
temperatures. Teague et al. (1968) and d’Arce et al. (1970) showed that gilts exposed to increased environmental temperatures during the estrous cycle before breeding had reduced estrous activity and pregnancy rate. Several studies have shown that embryo survival is adversely affected if gilts and sows are exposed to increased environmental temperatures immediately after breeding (Warnick et al., 1965; Tompkins et al., 1967; Edwards et al., 1968; Omtvedt et al., 1971; Hoagland and Wettmann, 1984). Omtvedt et al. (1971) found reductions (P<.01) in the number of viable embryos and a tendency for lower conception rates in gilts subjected to a cyclic elevated temperature, either 0 to 8 d after breeding, or 8 to 16 d after breeding. The reduction in number of viable embryos was greater in gilts exposed to cyclic increased temperatures from 8 to 16 d after breeding than in gilts exposed from 0 to 8 d after breeding. In addition, only 8 of 14 gilts in the 0- to 8-d exposure group, 11 of 14 gilts in the 8- to 16-d exposure group and 28 of 28 in the control groups were pregnant at 30 d. Apparently conception and subsequent embryonic survival were adversely affected by increased temperatures at breeding, and blasto- cysts were susceptible to high environmental temperatures during early implantation (d 12 through 16). Twenty days after breeding and until late gestation, the embryo/fetus becomes relatively resistant to changes in temperature. Gilts exposed during late gestation (102 to 110 d after breeding) farrowed fewer live pigs (6 vs 10.4 pigs), more stillborn pigs (5.2 vs .4 pigs) and litters with lower birth weights (8.6 vs 13.6 kg) than did control gilts (Omtvedt et al., 1971). Recommendations for providing a cool environment for both boars and sows during hot summers have been made (Driggers and Stanislaw, 1973; Roller et al., 1973; Roller and Stombaugh, 1974; Wettmann and Bazer, 1985).

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