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EFFECTS OF EXPOSURE TO MATURE FEMALES ON SEXUAL DEVELOPMENT IN YOUNG BOARS

by

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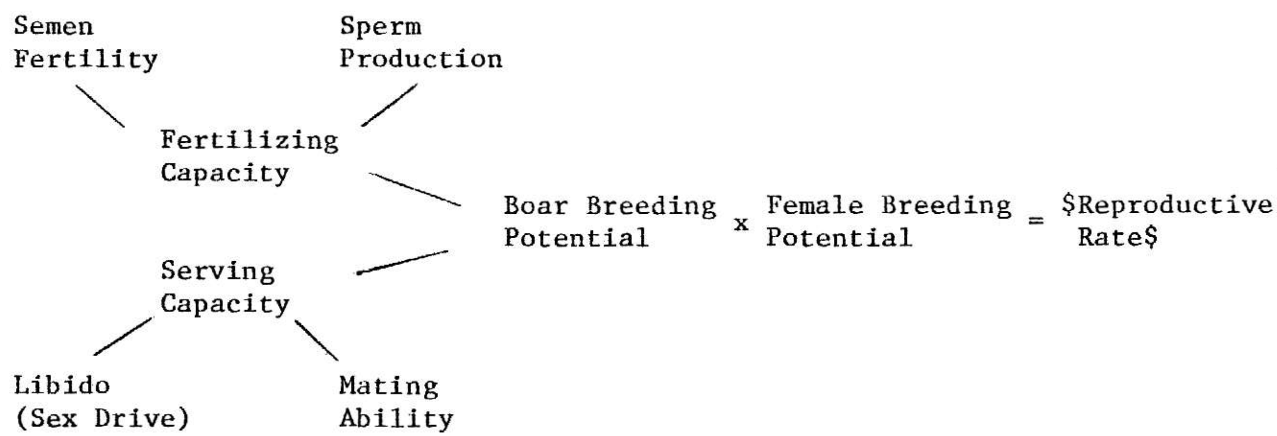
INTRODUCTION

The effects of social environment as related to farm livestock has been the topic of serious discussion for several years. More specifically the relationship between social environment and sexual development with reference to the pig has taken on added importance with the modernization of swine facilities. It is well known that age at puberty for gilts can be advanced by exposure to a mature boar, however, only recently has consideration been given to stimuli possibly affecting boar sexual development. Confinement rearing results in boars being raised in a system which often includes a restricted social environment without contact with female swine. Problems of reduced fertility, delayed sexual maturity, and decreased sex-drive have been reported. Since the swine industry uses predominantly young boars, research has been directed toward determining what factors affect ultimate reproductive performance of young boars. Mahone et al. (1979) studied the effect of artificially lengthening the photoperiod on the onset of puberty. Sperm concentration and total viable sperm per ejaculate were greater for boars receiving supplemental lighting (longer photoperiod). Esbenshade et al. (1979) compared confinement vs pasture rearing on reproductive development and performance of young boars. No differences were observed in recognition time of an estrus female, semen characteristics, growth rate, soundness, or rate of sexual development of young boars.

Little work has been reported on the relationship between social environment and sexual development of boars. Hemsworth et al. (1977a) found no differences in boars raised with prepuberal gilts vs an all male group but information on the influence of mature females on young boars is not available. This study was conducted to determine what effects exposure to mature female swine has on development of the reproductive organs and reproductive behavior of young boars. A second objective was to investigate procedures for predicting future sperm production and libido of young boars. Criteria measured were sexual behavior from 4 to 5½ months and various scrotal measurements. Figure 1 depicts the required "credentials" for an effective breeder. "Credentials" evaluated in the present study were sperm production, libido, and mating ability. Hopefully these data will be useful in developing techniques for predicting reproductive ability at an early age.

Figure 1. Credentials for an effective breeder.

Credentials for Effective Breeders:



LITERATURE REVIEW

Effect of Female Presence on Male Reproductive Behavior

Both the male and female must perform essential behavior if reproduction is to be successful. These behavioral reactions in the pig have been discussed by Signoret (1971). Three major phases were identified with regard to mating behavior. First there is mutual searching for the sexual partner. In searching for the sexual partner, the female plays the major role; the male's reaction being oriented largely by the behavior of the female. Second are pre-copulatory patterns of behavior. The reaction was described as follows; the female becomes immobile, archs her back, cocks her ears, and is completely rigid. Stimuli provided by the male increases the female's receptivity. Third is the mounting reaction of the male. Visual and tactile responses provided by the shape of the female and her immobility triggers the mating response by the male. The obvious conclusion is that the female plays an active role in determining the pattern of sexual behavior; the active search for the boar and the standing reaction being the main elements. The male's reaction appears to be governed by the female's responses.

Social experience during rearing has a profound effect on the sexual behavior of the male of several species. Hemsworth et al. (1977a) showed that total number of copulations and the sum of all courting behavior activities were significantly greater for boars reared in all-male and mixed sex groups than for those reared individually. This finding raises several questions about the relationship between rearing systems and ultimate reproductive behavior.

Sexual behavior of male rats is known to be effected by social restriction. Male rats raised individually actively circled and nuzzled the estrus females but they neither mounted or clasped her properly nor achieved intomissions (Gerall et al., 1967). Permitting cohabitation with normal females for at least three weeks restored these copulatory activities. Drori and Folman (1964) reported a severe atrophy of the reproductive system in unmated, grouped male rats compared to males in cohabitation with female rats. Male rats raised in individual cages were compared to grouped males provided different intensities of female odors (Folman and Drori, 1966). Again the penis and seminal vesicles of socially restricted rats atrophied. It was concluded that isolation, grouping, and continuous exposure to female odors have only minor effects on the reproductive system of unmated males.

Work done by Mason (1960) with rhesus monkeys demonstrated an effect of restricted social experience on social behavior. Monkeys reared individually showed brief sexual behavior and had gross deficiencies in organization. Numerous restricted males attempted mounts from the side and females frequently failed to assume appropriate receptive postures in response to sexual advances of individually raised males. Grasping the partner with the hands appeared early in testing, but throughout the experiment this response was less stereotyped and precise among restricted males and was often accompanied by nipping, tugging, or other playful behavior.

From work with male guinea pigs, Valenstein et al. (1955) concluded the following: (a) contact with other animals has an organizing action on the development of the copulatory pattern of the male guinea pig; (b) the influence of contact may be exerted very early in the life of the animal; (c) genetic differences between strains of guinea pigs are responsible for differences in the age at which organization of sexual behavior takes place and the amount of sexual excitement exhibited during testing; (d) genetic differences in level of sexual excitement are not overcome by the administration of large quantities of exogenous androgen; and (e) contact with males or females generally provides sufficient experience for the organization of the copulatory pattern.

Valenstein et al. (1954) found that highly inbred strains of male guinea pigs were significantly lower in sex drive and had significantly smaller variances than heterogenously bred animals. Therefore a genetic basis for mating behavior was suggested.

Hemsworth et al. (1977b) demonstrated influences of social conditions after puberty on sexual behavior of boars. Three groups of four mature boars were housed in individual pens for 3 months and either penned near ovariectomized female pigs induced into sexual receptivity at 2 week intervals, isolated from female pigs but with visual and physical contact with neighboring boars or with no exposure to boars or sows. The total number of copulations achieved in six mating tests through the 3 month period was greater ($p < .01$) for the boars housed near sexually receptive females than for those housed in the other two social conditions. For the subsequent 3 months all boars were housed near sexually receptive females and no differences were observed between the three groups for total number of copulations. However, the observations during the restoration period indicated that boars of high copulatory performance were more adversely effected after the isolation period than boars of lower copulatory performance. Thus boars of high sexual motivation may require a higher level of sexual stimulation in the long term to maintain their relative sexual behavior than boars of lower sexual motivation, and stimuli provided by sexually receptive female pigs are necessary to maintain high levels of sexual behavior in the boar.

Pheromones are a possible stimulus provided by adult females. Beach and Gilmore (1949) studied the attractants put forth by the estrus bitch. Dog owners who have kept adult females know that when a bitch comes into heat every male in the vicinity appears to be attracted to her dwelling place. The bitch urinates more frequently when she is in heat and in ranging over her territory the estrus female lays down a series of odor trails which converge upon her place of residence. It is accepted that male dogs respond to estrus urine and that the bladder contains the attractants.

Effect of Female Presence on Testes and Accessory Gland Development

Illius *et al*. (1976) studied yearling and immature rams during the normal breeding season. Yearling rams raised adjacent to ovariectomized ewes, which were induced to show estrus, had larger testes, higher plasma testosterone levels and greater sexual and aggressive activities than yearling rams not exposed to ewes. Immature rams were not affected by female exposure. Similarly, Bramley and Neaves (1972) demonstrated that bulbourethral gland weight and plasma testosterone levels were higher in male impala with access to females than in bachelor males.

Fox (1968) found that prepubertal habitation conditions had different effects on the reproductive physiology of the male house mouse.

At a predetermined date males raised in cohabitation with females had larger testes and epididymides than mice raised individually or raised in all-male groups. Also, wild males raised with an adult female were significantly more mature than wild males in either of the other two conditions. Vandenbergh (1971) reported similar results when albino male mice were reared with an adult female, yet, the presence of an adult male had an inhibitory effect on testicular and accessory gland development. These studies demonstrate that the presence of an intact adult female bestows reproductive advantages upon young male mice. However, these advantages did not persist until adulthood.

Effect of Male Presence on Immature Females

Much work has been done to determine the effects of male presence on sexual development and behavior of females. Brooks and Cole (1970) found that gilts raised in isolation from boars reached puberty later than gilts exposed to boars. Also, considerable synchrony of estrus was obtained when there was a rotation of boars used for detecting estrus, but the synchrony was much less marked when only one boar was used.

Mavrogenis and Robison (1976) demonstrated that age at puberty may be hastened by exposing gilts to a boar at the right stage of their development. The presence of boars substantially reduced ($p < .01$) age and weight at puberty, when exposed to boars at an average age of 140 days. Also, group size had a significant effect on sexual development. Age and weight at puberty were substantially reduced for gilts grouped 30 to a pen vs those individually penned.

Several experiments have indicated that exteroceptive factors provided by males influence reproductive events in female mice. Vandenbergh (1967) showed that female maturation, as measured by age at vaginal opening, first vaginal estrus, and first mating, was accelerated in proportion to the length of exposure to an adult male. Vandenbergh (1969) concluded that odors derived from males exposed to estrous females are more effective than odors from solitary males in accelerating sexual maturation. Colby and Vandenbergh (1974) used male urine to affect sexual behavior. They found the older the mouse at the time of first exposure to male mouse urine, the faster its subsequent sexual development. Exposure to male urine tended to shorten the interval between vaginal opening and first estrus, indicating that the pheromone does not "trigger" puberty, but instead accelerates the process of sexual maturation. Puberty was hastened by exposure to urine from either preputialectomized male mice or adult male rats, indicating that the preputial gland does not contain the priming pheromone and that the pheromone is not unique to the male mouse. Urine from castrated male mice was ineffective. In contrast to the acceleratory effect of male urine, urine from grouped adult female mice retarded sexual maturation. The urine of both sexes of adult mice, therefore, contains pheromones that alter sexual development of the female, but the pheromones are opposite in their regulatory effects on puberty.

Signoret (1970) raised gilts from birth until 8 months of age without physical contact with other pigs. When tested in a T-maze apparatus, with a choice of male attraction vs female attraction, anestrous gilts were equally attracted by a boar or another gilt. Gilts were ovariectomized and when estrus was induced they spent more time near the boar.

Chemical attractants put forth by the boar have a widely recognized effect of eliciting sexual behavior of females. Hillyer (1976) found that treatment of sows post-weaning with a synthetically produced porcine pheromone hastened post-weaning estrus. Treated sows were given either a one two-second spray of the synthetic pheromone on the nose, at day two following weaning or two sprays one on day two and a second on day four following weaning. Pheromone treatment reduced the average number of days from weaning to conception. There was no difference between one or two sprays and no differences between treated and control sows in the number of pigs born alive or litter weight at birth.

Sexual Development of Boars

The age at which boars reach puberty affects the efficiency of swine production. Puberty is defined as the time when an animal undergoes the morphologic, physiologic, and psychic transformations resulting in the ability to participate in sexual reproduction. This change is the result of hormonal changes. There can be no doubt that sex hormones are the cause of many of the changes, since they do not occur in the absence of these hormones. Puberty is usually measured either by the age of first sperm production of the age of sexual desire. Delays in puberty can result in losses related to late litters, replacement of boars, or alterations in planned breeding programs. Green and Winters (1945) studied the secretion of male hormones and the reaction to them, as well as the rate of development of the sperm producing elements in lines of inbred swine. The rate of testicular growth and development was consistently more closely associated with increases in body weight, than with age.

The lines differed in the amount of male hormone secreted, in testicular weight, and in seminiferous tubule development. Also, lines differed in the age of appearance of ranting and amount of sex drive.

Colenbrander *et al*. (1978) investigated serum levels of testosterone and luteinizing hormone (LH) in pigs during fetal and postnatal life. Serum testosterone concentrations were elevated between 40 and 60 days *post coitum*, yet, were quite low between 60 and 100 days *post coitum* when the testes descend. Between 60 days *post coitum* and 16 weeks after birth changes in serum testosterone concentrations paralleled those of testicular development as determined by morphology and steroid histochemistry, and were related to peripheral LH concentrations. The concentration of serum testosterone rose to significant levels at approximately 18 weeks of age. Leydig cells show a high degree of differentiation between 35 and 40 days *post coitum*, possibly explaining the increased level of serum testosterone a short time later (Moon and Hardy, 1973).

Similar changes in androgen levels have been shown for other species. Hooker (1942) suggested that at puberty target tissues for the reproductive hormones acquired the ability to respond to levels of androgen that had previously been ineffective. When rats are castrated at birth they exhibit the greatest response to injected testosterone at the age when accessory organs would normally undergo their most profound alteration. Macrides et al. (1974) reported significant changes in plasma testosterone levels following the placement of a receptive female into a male hamster's cage. Exposure to the vaginal discharge, in the absence of the female hamster, significantly increased plasma testosterone, thus demonstrating a direct effect of a sex-related odor on neuroendocrine activity in a male mammal.

FlorCruz and Lapwood (1978) reported the age at onset of spermatogenesis varied between boars, however, the range was 90 to 127 days. First observations of spermatozoa in seminiferous and epididymal tubules were made at 127 and 146 days of age respectively. Mean testosterone levels were low in the prepuberal period, then between 110 and 138 days increased drastically.

After puberty the boar's reproductive capacity continues to increase as indicated by semen characteristics Swiestra (1973). When 36-week-old boars were placed on a 72-hour collection schedule sperm concentration, total sperm, and motile sperm per ejaculate initially decreased as a result of the depletion of epididymal sperm reserves which had built up during prior sexual rest. However, after the initial decline, all semen characteristics increased as a result of growth of their reproductive glands.

Swiestra and Rahnefeld (1967) reported that the left testicle was significantly heavier ($p < .05$) than the right testicle in young Yorkshire boars. Sperm output was highly correlated with testis weight; however, there was no significant correlation between body weight and total semen volume, or between body weight and total sperm per ejaculate.

Scrotal circumference in living Holstein bulls was found to be a better measure of testis size than various linear measurements (Hahn _et al._, 1969). Correlation between testis size and sperm output was very high in young animals but decreased with age. These results indicated that the prediction of sperm output from the measurement of scrotal circumference should be valuable in young bulls, but holds little promise in older bulls. Willert and Ohms (1957) had previously reported that testis circumference and testis weight were positively correlated with number of sperm obtained by frequent ejaculation and with gonadal reserves.

Kennelly and Foote (1964) reported results of different locations of testis samples as a representative of the entire organ. Four predetermined areas were sampled to determine if each area was representative of the entire organ. Locations sampled contributed less to the total variance than did boars, and sides contributed nothing to the variance. This indicated that both testis were representative of the animal, and that the procedure of sampling one testis per animal from twice as many animals is more efficient than sampling both testis of fewer animals.

The epididymis shows a developmental relationship concerned with fertilizing ability in the boar. Hunter et al. (1976) found that as boar spermatozoa proceeds through the corpus region of the epididymal duct the ability for fertilization is gradually acquired. Horan and Bedford (1972) reported that in the Syrian hamster, spermatozoa does not normally acquire the ability to penetrate eggs until they reach the proximal portion of the cauda epididymis. These combined reports verify the epididymis as an important anatomical structure in male sexual development.

Egbunike and Elemo (1978) found that testicular and epididymal sperm reserves of 32 adult crossbred European boars (mean age 17.4 months) were 43.77×10^9 and 207.20×10^9 cells respectively, and were correlated ($p < .01$) with age and testis weight. The distribution of spermatozoa in the epididymis was 16, 6, and 78% in the caput, corpus, and cauda epididymides respectively. The testicular and epididymal sperm reserves were correlated ($p < .05$), suggesting that sperm production and storage are associated.

Wettemann and Desjardins (1979) demonstrated that elevated ambient temperature lowered fertility, increased sperm morphological abnormalities, decreased sperm output, and interfered with spermatocyte and/or spermatid maturation. In addition, heat stress caused a transitory decline in plasma testosterone concentration resulting from alterations in testicular androgen biosynthesis.

Libido

The term libido is commonly used to describe sex-drive. Knowledge of the factors influencing sex-drive and mating behavior of boars is necessary in order to properly select and use young boars in breeding programs. It is commonly known that lack of libido constitutes a major cause of boar wastage. Accurate assessment of boar sex-drive could be valuable in studies of hormonal, environmental, and genetic influences on boars. Chenoweth and Osborne (1975) described the use of estrus induced ovariectomized heifers to study differences in reproductive behavior of young beef bulls. Heifers were used on up to four successive days for testing and examination for libido and mating ability was performed in a small yard where the bull and heifer could be easily observed. Bulls were admitted individually and were allowed five minutes with a heifer that would stand while other heifers mounted her. If the selected heifer proved to be unreceptive when exposed to the bull she was replaced. All reactions and movements of the bull during the test were recorded on magnetic tape which was later replayed and a libido score was assigned. Each bull was tested twice at each test period and the worst result of the two discarded. Chenoweth (1977) concluded that bulls vary considerably in libido and mating ability and the major influence on these factors in young bulls is genetic. Also, libido and mating ability contribute to fertility prognosis in young beef bulls destined for natural service. It was suggested that while not a practical proposition for all bulls under going routine examination for breeding soundness, certain groups of bulls; such as young bulls coming off feeding trials, sale bulls of registered breeders, and bulls destined for artificial breeding should be considered for libido assessment.

The relationship between libido and fertility was substantiated by Corah et al. (1979). In six of nine cases, the bull pre-evaluated as most sexually active was the sire of the most calves, when paired with a low libido bull of another breed. This work is in agreement with Neville et al. (1979) who found that, regardless of age, some bulls settled their cows earlier in the breeding period and/or had a higher percentage of their cows settled by the end of the breeding period. Similarly, Lunstra et al. (1979) evaluated libido-fertility relationships in yearling beef bulls. After each bull was classified as high, medium, or low libido; fertility was assessed under controlled handmating conditions. Pregnancy rate for high and medium libido bulls was significantly higher ($p < .05$) than for low libido bulls. These studies indicate that libido in beef bulls can be evaluated effectively and that bulls exhibiting low libido have poor reproductive performance.

The assessment of libido and mating ability is important because it can help in the detection of physical abnormalities. Blockey (1975) submitted 548 bulls to a normal breeding soundness examination and to a serving capacity test. He found 113 bulls unsound for breeding. Of these, 31 had clinical abnormalities. The abnormalities diagnosed included penile deviations, penis-prepuce adhesions, and joint diseases. A further 17 bulls were culled on the basis of poor serving capacity. Only through a practical means of testing can these abnormalities be detected.

Mating tests conducted on boars have been reported by Hemsworth et al. (1977a). The libido test consisted of allowing each boar a 5 minute familiarization period alone in the mating pen and then introducing a randomly selected sexually receptive gilt. Gilts were ovariectomized and estrus was induced by estrogen injections. Receptive gilts were identified by their response to hand pressure on the back in the presence of boars (Signoret, 1970). The following sexual behavior activities of the boar, and their times of occurence were recorded: naso-nasal contact; nosing the sides of the gilt; ano-genital sniffing; "chanting" (short series of characteristic grunts); mounting; intromission; and ejaculation. After each copulation the gilt was removed and a "fresh" receptive gilt was introduced and the test continued until 20 minutes had elapsed. A boar was considered to have achieved a copulation with a gilt when the duration of ejaculation was at least 1.5 minutes.

While techniques for evaluation libido, mating ability, and testicle size, are not well established for use in the boar the potential usefulness of these measurements is substantial. Hopefully, techniques will be developed which are feasible for widespread application.

MATERIALS AND METHODS

Thirty-two Yorkshire boars (16 littermate pairs) were used for this study. All pigs were farrowed within a two week period in February 1979, were weaned at approximately 5 weeks of age and were allotted to treatment groups by litter. Boars were reared in two groups in the KSU nursery and at approximately 2½ months of age, they were moved to a modified open front building and fed a free choice 18% corn-soybean meal diet (table 1). When the average age was approximately 3½ months, all boars were moved to outside lots. Controls were raised in a single pen isolated from other pigs, while the treated group was raised in a single pen with fenceline contact with 50 adult cycling females until 5½ months of age. Pen size was 6m x 20m for both groups and 32m of fence were common to mature females for treated boars. A small open front shed (3m x 6m) was provided in both pens and a 16% free choice corn-soybean meal diet was fed to both groups (table 2). At 5½ months of age 6 randomly chosen littermate pairs (six treated and six exposed boars) were slaughtered to determine the effects of rearing system on sexual development (see table 3 for experimental design). The remaining 20 boars were moved to adjacent individual pens (1.3m x 4.1m) with every other pen occupied by a boar previously reared in isolation. Libido tests were conducted at 6½ and 7½ months on these remaining boars. At 7½ months of age another 12 randomly chosen boars (six from each treatment group) were slaughtered. The final eight boars were reared in individual pens until 9½ months of age, when two libido tests (on consecutive days) were conducted and the experiment terminated (November 1979).

TABLE 1. COMPOSITION OF RATION FED TO NURSERY BOARS[a]

Ingredient	International reference number	Percent
Yellow corn	4-02-935	69.65
Soybean meal (44%)	5-04-604	26.25
Dicalcium phosphate	6-01-080	1.75
Ground limestone	6-02-632	1.00
Salt		.50
Trace mineral premix[b]		.10
Vitamin premix[c]		.50
Antibiotic[d]		.25
		100.00

[a]Provided as a meal diet.

[b]Containing 0.1% cobalt, 1.0% copper, 0.3% iodine, 10% iron, 10% manganese and 10% zinc.

[c]Amounts per kg: Vitamin A, 881,000 U.S.P.; Vitamin D_3, 66,000 U.S.P.; riboflavin, 991 mgs; d-pantothenic acid, 2,650 mgs; choline, 66 mgs; niacin, 5,500 mgs; Vitamin E, 4,400 I.U.; Vitamin B_{12}, 4.8 mgs; Vitamin K, 550 mgs; antioxidant, 6.3 mgs.

[d]Supplied as 55 mgs Mecadox per kg of diet.

TABLE 2. COMPOSITION OF RATION FED TO GROWING BOARS[a]

Ingredient	International reference number	Percent
Yellow corn	4-02-935	74.55
Soybean meal (44%)	5-04-604	22.00
Dicalcium phosphate	6-01-080	1.50
Ground limestone	6-02-632	.70
Salt		.50
Trace mineral premix[b]		.10
Vitamin premix[c]		.50
Antibiotic[d]		.15
		100.00

[a]Provided as a meal diet.

[b]Containing 0.1% cobalt, 1.0% copper, 0.3% iodine, 10% iron, 10% manganese and 10% zinc.

[c]Amounts per kg: Vitamin A, 881,000 U.S.P.; Vitamin D_3, 66,000 U.S.P.; riboflavin, 991 mgs; d-pantothenic acid, 2,650 mgs; choline, 66 mgs; niacin, 5,500 mgs; Vitamin E, 4,400 I.U.; Vitamin B_{12}, 4.8 mgs; Vitamin K, 550 mgs; antioxidant, 6.3 mgs.

[d]Supplied as 33mgs tylosin per kg of diet.

TABLE 3. EXPERIMENTAL DESIGN

Item	Procedure	Controls	Exposed to mature females
No. of boars		16	16
Average age			
3½ - 5½ Months	Behavior observations	Isolated	Fenceline contact with cycling females
5½ Months	Slaughter	6 Boars	6 Boars
6½ Months	Libido test	10 Boars	10 Boars
7½ Months	Libido test	10 Boars	10 Boars
7½ Months	Slaughter	6 Boars	6 Boars
9½ Months	Libido tests	4 Boars	4 Boars

Behavior

Between 4 and 5½ months of age, pigs were observed for 1 hour each day (0700 - 0800 hr) for behavioral activities. Three investigators served as observers and two of the three recorded boar activities during each observation period, with one observer stationed at each pen. Observers rotated so that an equal number of observations were made by each recorder at each pen. The following acts were recorded: naso-nasal contact; nosing the side of other boars; sheath sniffing; anal sniffing; "chanting" (short series of characteristic grunts); mounting; extension of the penis; thrusting; rectal intromission; and ejaculation.

Sexual Development

Beginning at 3½ months of age and henceforth at approximately 30 day intervals, several measurements were taken to evaluate boar development. The measurements included the following: body weight; individual testis length and width; combined testis width; testis partial circumference for length and width; and combined testis partial circumference for width. Testis length and width were measured with calipers, while partial circumference was measured with a flexible wire cable. Width measurements were made at the widest part of the testicle and partial circumference measurements extended between the apex of the angles formed by the testicle and the ham. All boars were physically restrained while measurements were taken (Figure 2). Also, testicle size was scored visually by two observers. Scores were from 1 to 5; 5 being extremely large testes and 1 indicating extremely small testes.

Further measurements of sexual development were taken at slaughter

Figure 2. Restriction method for scrotal measurements.

and included: testis weight; testis volume; tunica albuginea weight; epididymal head and body weight; and epididymal tail weight. Also, the following sex accessory glands were closely trimmed and weighed: seminal vesicles; bulb of the prostate; and bulbourethral glands. In addition, several testicle measurements were taken for comparison with scrotal testicular measurements.

The tunica albuginea was removed from each testis and weighed. A small tissue sample (5 grams) was taken from three regions of each testis corresponding to the caput and cauda epididymis and a sample half way between the two. These samples were used for analysis of differences between boars and between treatments for total sperm production as well as sperm per gram of testicular tissue. Region differences were also analyzed for within testicle differences in sperm production. Because Kennelly and Foote (1964) found that location sampled contributed less to the total variance than did boar, and side contributed nothing to the variance, only left testicle samples were used for sperm production determinations. Since testicular homogenates prepared by the method of Amann and Almquist (1961) contain particulate matter which may obscure spermatid heads during hemacytometric counts, a different medium was used. Triton X-100 (.05%) was added to a .9% NaCl solution to eliminate tissue debris (Amann and Lambiase, 1969). Also, 100 ppm methiolate was included to retard bacterial growth. Each testis sample was minced into very fine pieces and added to 100 ml of medium. This solution was then placed in a blender and homogenized for 2 minutes. After allowing the samples to set for 12 hours, sperm counts were made. Sperm counts were determined with a hemacytometer and concentration per gram of testicular tissue were calculated as in the procedure by Perlman (1971) and Sorenson

(1971). All samples were counted on a phase contrast microscope at a magnification of 640X. Total testicular sperm was determined by calculation [sperm/gram x (testis weight - tunica albuginea weight)]. Left tail epididymal samples were added to 200 ml of medium and homogenized for five minutes. Sperm counts were made from these homogenates as described above. The data obtained was used to calculate total cauda epididymal sperm reserves. One female exposed boar was unthrifty and had evidence of renal failure at slaughter at 5½ months of age. This boar and his littermate were not included in data summaries.

Mating Tests

Libido tests were conducted at the time intervals previously described, early in the morning. Estrus was induced in ovariectomized gilts with a subcutaneous injection of estradiol benzoate (4 mg/head) 72 hours before the libido test. Gilts were checked for behavioral estrus with a boar and only those exhibiting "standing estrus" were used. The test consisted of a five minute famaliarization period in a pen with fenceline contact with ovariectomized estrus induced gilts. Then, the boar and an estrus gilt were placed in a pen (3m x 12m) not adjacent to other pigs, where the mating test was conducted. During the test the following was recorded: naso-nasal contact; nosing the side of the gilt; ano-genital sniffing; chanting; mounting; extension; thrusting; and collection. An attempt to collect each boar was made if mounting, extension, and thrusting occurred. Volume of collected semen was measured and motility was scored. A sample was fixed in buffered formal (table 4) for later morphological evaluation and another sample was taken

TABLE 4. BUFFERED FORMAL SALINE[a]

Ingredient	Amount/liter
Na_2HPO_4	4.93 g
KH_2PO_4	2.54 g
NaCl	5.41 g
Formaldehyde (38%)	125.00 ml
Distilled H_2O - to total volume of one liter	

[a]Hancock, J. L. 1957.

for determining concentration. If a boar was collected the mating test was terminated, but if a collection was not made a maximum of 15 minutes was allowed. Each boar was given a libido score according to the following criteria:

1 - No interest in the gilt.

2 - Some interest, no mount.

3 - Mounting (correct orientation).

4 - Mounting, extension, thrusting.

5 - Mounting, extension, thrusting, and collection.

Fixed samples were evaluated using phase contrast microscopy at a magnification of 640X. The following was recorded: sperm concentration; % abnormal forms (Sorenson, 1971); % proximal cytoplasmic droplets and % distal cytoplasmic droplets.

Statistical Analysis

Data were analyzed using least squares analysis of variance (Kemp, 1972). If significant differences were detected means were compared using Duncans New Multiple Range Test (Duncan, 1955).

RESULTS

Behavior

More sexual acts were observed for boars with fenceline exposure to females from 3½ to 5½ months of age than in boars not exposed to females (table 5). Total sexual acts were determined by totalling the following behaviors for the actor: sheath sniffs; side nosing; anal sniffs; and mounts. There was a trend for more sexual acts for female exposed boars, however, significant differences were not detected. Total sexual acts for individual boars during the 6 week observation period was correlated with libido score at 6½ and 7½ months ($r=.69$ and $.68$ respectively; $p<.05$). While it was not possible to determine a dominance order in this experiment boars observed to fight more frequently during the daily observations, scored lower in libido tests ($r= -.21$, $p=.37$ at 6½ months and $r= -.27$, $p=.24$ at 7½ months). An interesting example was presented by one boar frequently observed in combat with other boars who fought with the estrous female. This boar did not respond sexually toward an estrous gilt until the final libido test, at 9½ months of age. The relationship between behavior during rearing and post-puberal mating behavior deserves further study. Boars exposed to females tended to show more sexual acts (table 6).

Sexual Development

Development of the reproductive tract was determined by measurements of the testes and sex accessory glands obtained at slaughter. Boars reared next to sexually mature females had smaller testes at both 5½ and

TABLE 5. SEXUAL BEHAVIORS OBSERVED FROM 16 TO 22 WEEKS OF AGE

Sexual acts	Control[a]	Exposed[a]
Nosing side of males	72	137
Sheath sniffs	440	387
Anal sniffs	87	129
Mounts	346	383
Extension	93	117
Thrusts	49	71
Penetrations	8	8

[a]Values are the sum for all 16 boars in the pen.

TABLE 6. CORRELATIONS BETWEEN SEXUAL ACTS AND LIBIDO SCORE

Sexual acts	Libido score 6½ month	Libido score 7½ month
Sheath sniffs	.67*	.56^t
Mounts	.55^t	.60^t
Nosing side	.42	.48
Anal sniffs	.28	.29
Total sexual acts	.69*	.68*

$^t p < .10$.

$^* p < .05$.

7½ months. However, both right and left epididymal weights tended to be heavier for boars exposed to females at 5½ months. By 7½ months of age any advantage in epididymal weight had disappeared (table 7). In addition the sex accessory glands tended to be heavier for the exposed group at 5½ months (table 8). No statistically significant treatment effects were detected for slaughter data ($p > .10$).

Sperm per gram of testicular tissue tended to be greater for boars exposed to females at the 5½ month slaughter age (69 vs 49 x 10^6; p=.13). Additionally, boars exposed to females tended to have more sperm per testicle (11 vs 9 x 10^9) at 5½ months of age. Similar trends were found for sperm reserves as estimated by cauda epididymal sperm (table 9). However, these trends were not apparent in boars slaughtered at 7½ months and no differences in region of testis sampled were found.

Boars exposed to females were lighter at 5½ (p=.11) and 7½ months (125.4 vs 135.4 kg for control and exposed boars, respectively, $p < .05$). Calculated days to 100 kg was 191 days for female exposed boars vs 185 days for controls.

Testicle Measurements

The possibility of using caliper and partial circumference measurements to predict testicle weight was investigated. Each scrotal measurement was evaluated as a predictor of combined testes weight (table 10). Testicle weight is highly correlated with total testicle sperm in boars (Wilson et al., 1977, and see table 11 for this study). Flexible cable measurements (partial circumference) for right and left testicle length and combined testes provided the best prediction equation for testicle

TABLE 7. EFFECT OF EXPOSURE TO MATURE FEMALES ON TESTICLE AND EPIDIDYMAL WEIGHTS OF YOUNG BOARS

		Testicle weight (gm)		Epididymal weight (gm)			
Slaughter age	Treatment	Right Mean ± S.E.	Left Mean ± S.E.	Right tail Mean ± S.E.	Right head & body Mean ± S.E.	Left tail Mean ± S.E.	Left head & body Mean ± S.E.
5½[a]	Control	190.3 ± 16.9	192.1 ± 17.6	14.9 ± 2.1	19.3 ± 2.8	14.8 ± 1.7	19.6 ± 2.3
	Exposed	160.0 ± 16.9	169.4 ± 17.6	17.2 ± 2.1	20.4 ± 2.8	17.2 ± 1.7	20.4 ± 2.3
7½[b]	Control	349.0 ± 15.4	364.9 ± 16.0	26.9 ± 1.9	33.7 ± 2.6	29.1 ± 1.5	34.3 ± 2.1
	Exposed	318.6 ± 15.4	341.4 ± 16.0	24.4 ± 1.9	29.7 ± 2.6	26.5 ± 1.5	29.8 ± 2.1

[a]Values are least squares means of 5 observations.

[b]Values are least squares means of 6 observations.

TABLE 8. SEX ACCESSORY GLAND WEIGHTS

Slaughter age	Treatment	Bulb of prostate gland Mean ± S.E.	Seminal vesicle gland Mean ± S.E.	Bulbourethral gland Mean ± S.E.
5½[a]	Control	5.7 ± 1.2	44.5 ± 15.6	79.7 ± 13.8
	Exposed	6.6 ± 1.2	49.1 ± 15.6	92.1 ± 13.8
7½[b]	Control	14.3 ± 1.1	105.2 ± 14.3	183.5 ± 12.6
	Exposed	11.3 ± 1.1	101.0 ± 14.3	158.2 ± 12.6

[a]Values are least squares means of 5 observations.

[b]Values are least squares means of 6 observations.

TABLE 9. SPERM PRODUCTIONS AND SPERM RESERVES

Slaughter age	Treatment	Left testicle: Sperm/gram Mean ± S.E. ($X10^6$)	Left testicle: Total sperm Mean ± S.E. ($X10^9$)	Left tail epididymis: Sperm/gram Mean ± S.E. ($X10^6$)	Left tail epididymis: Total sperm Mean ± S.E. (10^9)
5½[a]	Control	49.3 ± 8.1	9.1 ± 3.1	347.6 ± 184.0	6.4 ± 3.6
	Exposed	69.2 ± 8.1	11.1 ± 3.1	606.4 ± 184.0	11.3 ± 3.6
7½[b]	Control	93.9 ± 7.4	32.8 ± 2.9	1,061.8 ± 102.1	30.9 ± 3.1
	Exposed	89.7 ± 7.4	28.9 ± 2.9	832.0 ± 102.1	22.9 ± 3.1

[a]Values are least squares mean of 5 observations.

[b]Values are least squares mean of 6 observations.

TABLE 10. CORRELATION BETWEEN SCROTAL TESTICLE MEASUREMENTS WITH TESTES WEIGHT

Measurements	5½ month[a] combined testes weight	7½ month[b] combined testes weight
Left length calipers	.46	.31
Right length calipers	.29	.47
Total width calipers	.48	.33
Left length flexible cable	.17	.10
Right length flexible cable	.19	.47
Total width flexible cable	.56[t]	.44
Visual score[c]	.53	.41

[a] Values based on 10 observations.

[b] Values based on 12 observations.

[c] Average score of two scorers.

[t] $p < .10$.

TABLE 11. CORRELATION BETWEEN SPERM PRODUCTION AND COMBINED TESTES WEIGHT

Testicle tissue	5½ month Testicle weight	7½ month Testicle weight
Sperm/gram	.11	.69*
Total sperm	.52	.92**

*$p < .05$.

**$p < .001$.

weight, ($r=.71$, at 7½ months of age; table 12) and other measures provided less reliable estimates.

Libido

Results of the libido test indicated no difference between treatments at 6½, 7½, and 9½ months. At 7½ months of age only 13 of 20 boars mounted an estrous female (7 control and 6 treated boars). This reflects a widespread problem encountered by swine producers and the libido test procedure may provide a means of studying libido and mating abnormalities. Interestingly, litter influenced libido score ($p< .05$). Whether the litter effect reflected genetic or early environmental influences could not be determined, however this source of variation merits further study.

TABLE 12. MODEL FOR PREDICTION OF TESTICLE WEIGHT

Measurement	Model	5½ month Equation	Correlation coefficient	7½ month Equation	Correlation coefficient
Calipers	Single variable:	$TW^{a} = 81.9 + 1.5TWC^{b}$	.48	$TW^{a} = 186.0 + 2.5RLC^{c}$	.47
	Two variable:	$TW^{a} = 77.6 - 3.0RLC^{c} + 4.4LLC^{d}$	.55	$TW^{a} = 240.4 + 4.8RLC^{c} - 2.5LLC^{d}$	.52
	Three variable:	$TW^{a} = 78.7 - 3.5RLC^{c} + 3.5LLC^{d} + 1.3TWC^{b}$	.62	$TW^{a} = 150.8 + 5.1RLC^{c} - 4.9LLC^{d} + 2.1TWC^{b}$	.55
Flexible cable	Single variable:	$TW^{a} = -101.1 + 3.9TWS^{e}$	$.56^{t}$	$TW^{a} = 19.5 + 5.1RLS^{f}$	.47
	Two variable:	$TW^{a} = -43.6 - 1.0RLS^{f} + 4.4TWS^{e}$	.57	$TW^{a} = -337.8 + 4.2RLS^{f} + 3.3TWS^{e}$	.58
	Three variable:	$TW^{a} = -45.9 - .6RLS^{f} - .4LLS^{g} + 4.4TWS^{e}$	.57	$TW^{a} = -294.1 + 7.8RLS^{f} - 5.3LLS^{g} + 4.5TWS^{e}$	$.71^{tt}$

[a] Testes weight.

[b] Total width calipers.

[c] Right length calipers.

[d] Left length calipers.

[e] Total width flexible cable.

[f] Right length flexible cable.

[g] Left length flexible cable.

[t] $p < .10$.

[tt] $p < .12$.

DISCUSSION

The swine industry uses predominantly young boars. While good estimates are not available it is generally agreed substantial numbers of boars prove unsatisfactory for breeding. This undoubtedly results in economic losses to swine producers. Number of pigs marketed/sow/year is recognized as an economically important trait. Therefore, sows must be bred at the earliest possible time and any problems related to boar failure contribute to reproductive inefficiencies. It has been estimated that 6 to 7% of all young boars are culled the first 60 days after purchase and as high as 18% of boars culled have inadequate libido (Nelson, 1976). Genetically valuable boars are often lost due to subnormal libido and/or mating ability. The relative contributions of heredity and environment to sexual development of young boars has received little research attention.

This study demonstrated that rearing boars in contact with sexually mature females tended to increase the size of the sex accessory glands at 5½ months of age. Behavior during rearing may have been affected by exposure to females. However, no statistically significant differences could be attributed to female exposure and the sex accessory glands of female exposed boars were lighter than controls at 7½ months. Apparently exposure to females had no large effects on sexual development. Exposure to females decreased body weight at 5½ months ($p=.11$) and 7½ months of age ($p=.05$). Possibly extending the period of exposure to sexually receptive females would have resulted in greater differences between treatments. Boars were prepuberal during the exposure period and this experiment did not consider possible effects of exposure to females on post-puberal boars.

Insitu testes measurements may potentially be useful for predicting sperm producing ability. However, the measurements considered in this study were less than adequate. The anatomical location of boar testes makes measurement difficult but further effort should be expended to develop accurate techniques for measuring boar testicles.

Perhaps the most striking observation was the positive relationship between sexual activity of the boars between 4 and 5½ months of age and post-puberal libido scores. It is possible that sexual behavior patterns are developing during this period, and if so, modification of sexual behavioral development during rearing should be possible. This contention is supported by the stimulatory effect of prepuberal group rearing (Hemsworth et al., 1977a) and extended photoperiod (Mahone et al., 1979) on post-puberal libido score. However, aside from these considerations, prepuberal sexual acts, as demonstrated in the present study is the first identified technique for predicting post-puberal libido during the prepuberal period. This relationship may be useful in boar selection programs if it can be confirmed in future studies.

SUMMARY

Thirty-two Yorkshire boars were allotted by litter to one of two treatments. Sixteen boars were reared from 3½ to 5½ months of age in fenceline contact with mature sows and gilts which were randomly exhibiting estrus. Sixteen littermates to the above boars were reared without exposure to females and served as controls. Boars were weighed at monthly intervals from 3½ to 7½ months of age. Six boars per treatment were slaughtered at 5½ months and another 12 boars (six per treatment) at 7½ months of age. Vesicular gland, bulb of the prostate gland, bulbourethral gland, testes, cauda epididymal and combined caput and corpus epididymal weights were recorded. Left cauda epididymis and left testis sperm were determined by homogenization and hemocytometer counting. Samples were counted on a phase contrast microscope at a magnification of 640X. Boars exposed to females tended to have more sperm per gram of testis at 5½ months, however, no significant differences were found. Slaughter data revealed a trend towards increased weight of all three sex accessory glands at 5½ months for female exposed boars, but these trends were not found at 7½ months. Boars exposed to females were lighter than controls at 5½ months and significantly lighter at 7½ months (125.4 vs 135.4 kg; $p < .05$).

At 6½, 7½, and 9½ months boars were tested for libido by exposure to an estrous gilt. Boars were given a score from 1 to 5, with 1 indicating no sexual interest in the female and 5 indicating interest, mounting, and ejaculation. Treatment did not affect libido score, but litter differences in libido score were detected ($p < .05$). From 4 to 5½ months boars were

observed for 1 hour per day and the incidence of sexual acts (sheath sniffs, anal sniffs, nosing the side, and mounts) recorded. Total sexual acts were correlated with libido score at 6½ and 7½ months (r=.69 and .68, respectively; $p < .05$). Data revealed a correlation between testicle size and total testicle sperm which was significant at 7½ months of age (r=.92; $p < .001$). Scrotal measurements with a flexible cable, prior to slaughter, gave the best prediction of testicle size (r=.71). Results indicate only limited effects on young boars of exposure to mature females, however there were strong indications of a relationship between boar behavior during rearing and post-puberal libido score.

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EFFECTS OF EXPOSURE TO MATURE FEMALES ON SEXUAL DEVELOPMENT OF BOARS

by

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Sixteen Yorkshire boars were reared from 3½ to 5½ months of age in fenceline contact with sows and gilts randomly exhibiting estrus. Sixteen littermates to the female exposed boars were reared without exposure to females and served as controls. Boars were weighed at monthly intervals. Scrotal measurements were taken with both a flexible cable (partial circumference) and calipers and were also visually scored to predict testicle weight. Twelve boars (six per treatment) were slaughtered at 5½ months and another 12 boars were slaughtered at 7½ months of age. Vesicular gland, bulb of the prostate gland, bulbourethral gland, testes, cauda epididymal and combined caput and corpus epididymis weights were recorded. Cauda epididymis and left testis sperm were determined by homogenization and hemocytometer counting. All samples were counted on a phase contrast microscope at a magnification of 640X. Boars exposed to females were lighter than controls at 7½ months (125.4 vs 135.4 kg; $p < .05$) and tended to have more sperm per gram of testis at 5½ months (69 vs 49 x 10^6; $p = .13$). At 6½, 7½, and 9½ months boars were tested for libido by exposure to an estrous gilt. Boars were given a score from 1 to 5, with 1 indicating no sexual interest in the female and 5 indicating interest, mounting, and ejaculation. Treatment did not affect libido score, but litter differences in libido score were detected ($p < .05$). From 4 to 5½ months boars were observed for 1 hour each day and the incidence of sexual acts towards other boars were (sheath sniffs, anal sniffs, nosing the side, and mounts) recorded. The number of sexual acts during the six week observation period were correlated with libido score at 6½ and 7½ months ($r = .69$ and .68; $p < .05$). Therefore, post-puberal libido score is related to behavior during rearing but exposure to mature females has little effect on boar reproductive development. A combination of three flexible cable measurements gave the best prediction of testicle size (r=.71).