INFLUENCE OF BREED ON TESTICULAR AND ENDOCRINE FUNCTION OF PUBERAL BOARS

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CHAPTER I

INTRODUCTION

Crossbreeding is used in commercial swine production because crossbred pigs reach market weight about 10 days earlier and convert feed to gain about three percent more efficiently than purebreds. In addition, a two-breed crossbred sow, when mated to a boar of a third breed, will produce about one extra pig per litter at weaning. These two factors, feed efficiency and number of pigs weaned, should be of utmost importance to a producer.

Good reproductive performance is essential for efficient swine production. Without good reproductive performance, a livestock enterprise can not be profitable. Studies investigating effects of crossbreeding on reproductive performance have primarily focused on gilts and sows. Very little emphasis has been placed on determing the effects of crossbreeding on boar reproduction. This is surprising, particularly in light of the tremendous popularity of "hybrid" swine and the exhaustive efforts of organizations to advertise, promote and market "hybrid" boars for use in commercial swine production. Past research has suggested that heterosis exists for testicular development and libido of boars as well as for greater

conception rates. However, these studies were limited either in the number of animals or number of breeds evaluated. Information must be obtained on several different breeds and crosses of boars before recommendations can be made to swine producers regarding the use of crossbred boars in commercial operations. The lack of information on performance of crossbred boars was the stimulus that caused this study to be initiated.

Testicular characteristics of purebred and two-breed crossbred boars of Duroc, Landrace, Spot and Yorkshire breeding were measured in order to corroborate or refute previous studies which employed only two breeds. These four breeds were chosen because information on crossbred boars of these breeds is limited or non-existent, and these breeds are very important to commercial swine production in the United States today. Previous research has suggested that, during development, crossbred boars differ physiologically from purebred boars. It is thought that this hypothesized physiological difference might account for the more rapid testicular development of crossbred boars. Because testosterone and luteinizing hormone (LH) are essential for normal reproductive processes, measurement of systemic quantities of these two hormones might serve as an index of reproductive development. Since testosterone and LH concentrations vary throughout the course of a day, GnRH was injected into the boars prior to blood sampling in an attempt to maximize hormone secretion in all boars.

This study probably will not tell us whether or not crossbred boars should be used in commercial swine operations to increase profit. However, it will provide much needed information on testicular development of purebred and crossbred boars of several breeds, as well as indicate whether breed influences systemic testosterone and LH concentrations.

CHAPTER II

LITERATURE REVIEW

Effect of Crossbreeding on Growth and Efficiency of Swine

Crossbreeding has been used in commercial swine production to increase profits. In general, crossbred pigs grow more rapidly and more efficiently than purebred animals.

Pre-Weaning Traits

Crossbred and purebred pigs usually have similar birth weights (Carroll and Roberts, 1942; O'Ferrall et al., 1968; Johnson and Omtvedt, 1973; Young et al., 1976a; Miller et al., 1979), however, some studies indicate a small increase in birth weight for crossbred compared to purebred pigs (Winters et al., 1935; Lush et al., 1939; Robison, 1948; England and Winters, 1953; Cunningham, 1967). Supportive of the latter claim, crossbred embryos may be slightly larger than purebred embryos at 30 days gestation (Johnson and Omtvedt, 1973). Differences between purebred and crossbred individual pig weights at weaning are small, but crossbreds are always heavier than purebreds (Winters et al., 1935; Lush et al., 1939; Robison, 1948; England and

Winters, 1953; Cunningham, 1967; Johnson and Omtvedt, 1973; Young et al., 1976a; Miller et al., 1979). Crossbred litters contain slightly more pigs at 30 days of gestation and at farrowing (Johnson and Omtvedt, 1973; Young et al., 1976a), and significantly more pigs at weaning (Winters et al., 1935; Lush et al., 1939; England and Winters, 1953; Whatley et al., 1954; Smith et al., 1960; Cunningham, 1967; O'Ferrall et al., 1968; Johnson and Omtvedt, 1973; Young et al., 1976a). The increase in litter size reflects increased survival of crossbred pigs compared to their purebred counterparts.

Post-Weaning Traits

Crossbred pigs grow faster than purebred pigs (Winters et al., 1935; Lush et al., 1939; Carroll and Roberts, 1948; Robison, 1948, Gregory and Dickerson, 1952; Tucker et al., 1952; England and Winters, 1953; Gaines and Hazel, 1957; Smith et al., 1960; Whatley et al., 1960; Cunningham, 1967; Kuhlers et al., 1972; Johnson et al., 1973; Young et al., 1976b; Wilson et al., 1978; Miller et al., 1979). The increase in growth rate results in the crossbreds reaching market weight about 1 to 2 weeks earlier than purebred pigs. The increased growth rate of crossbred pigs may result in increased feed efficiency (Winters et al., 1935; Lush et al., 1939; Gregory and Dickerson, 1952; Whatley et al., 1960; Johnson et al., 1973; Young et al., 1976b), however,

Tucker et al. (1952) and Kuhlers et al. (1972) found no difference in feed efficiency between crossbred and purebred pigs.

Influence of Crossbreeding on Reproductive Performance of Gilts and Sows

Crossbred gilts attain puberty, as evidenced by first estrus, at a younger age than purebred gilts (Squiers et al., 1952; Foote et al., 1956; Reddy et al., 1958; Zimmerman et al., 1960; Clark et al., 1970; Johnson et al., 1978; Hutchens et al., 1979b). Although Baker et al. (1969) indicated a greater farrowing percentage for crossbred than for purebred sows, conception rate and ovulation rate were similar for purebred and crossbred gilts and sows (Johnson et al., 1978). Squiers et al. (1952) reported significantly more ova ovulated per crossbred gilt when compared to purebreds. Crossbred gilts have significantly more embryos at 25 (Squiers et al., 1952), 30 (Johnson et al., 1978) or 55 (Reddy et al., 1958) days of gestation than purebred gilts. Also, crossbred sows and gilts farrow and wean more pigs per litter than purebreds (Winters et al., 1935; Robison, 1948; Bradford et al., 1960; Cunningham, 1967; Johnson and Omtvedt, 1975; Johnson et al., 1978).

Effect of Crossbreeding on Reproductive Performance of Boars

Pubertal Development

Crossbred boars exceeded parental lines by 28 percent for body weight, 30 percent for testis weight, 27 percent for epididymidal weight and 20 percent for the stage of spermatogenesis (Hauser et al., 1952). Significant heterosis occurred for testis weight, caudae epididymidal weight and total testicular sperm numbers in 7.5 month old Duroc X Hampshire crossbred boars (Wilson et al., 1977). Similarly, at 5.5 months of age, Duroc X Yorkshire crossbred boars had larger testes and epididymides and more total testicular sperm than purebreds (Neely et al., 1979). Even after adjustment for body weight differences, the crossbred boars had larger testes and more testicular sperm. This suggests a true physiological difference in these puberal boars.

Fertility

Limited information suggests a greater conception rate for crossbred than for purebred boars (Baker, 1973; Wilson et al., 1977; Hutchens et al., 1979a) as well as greater embryo survival to 30 days of gestation (Wilson et al., 1977) for embryos sired by crossbred boars. In contrast, a very similar limited study revealed that conception rates were similar for sows bred to either crossbred or purebred

boars (Drewry, 1980). Hutchens et al. (1979a) noted that litter size was similar for crossbred litters sired by purebred or crossbred boars.

Sexual Behavior

Limited information is available on the sexual behavior of purebred and crossbred boars. A study with 7.5 to 9 month old purebred and crossbred Duroc and Hampshire boars demonstrated that 28 of 36 crossbred boars mated each time they were exposed to an estrous gilt, whereas, only 11 of 36 purebreds mated at each time exposed to an estrous gilt (Wilson et al., 1977). In general, differences between crossbred and purebred boars for time required to mount after exposure to an estrous gilt and duration of ejaculation were small and non-significant (Wilson et al., 1977). In contrast, research from North Carolina State (O. W. Robison, unpublished data) has indicated significant heterosis for mating behavior and libido scores when Duroc and Yorkshire breeds were involved. Supportive of this claim, crossbred Landrace X Yorkshire, Hampshire X Yorkshire and Hampshire X Landrace boars were younger at first semen collection than purebred Yorkshire and Landrace boars (Sellier et al., 1973). The breeds involved may influence the amount of heterosis exhibited for different reproductive traits by crossbred boars.

Factors Affecting Puberty in Boars

Boars may have sexual interest at a few weeks of age but are not fertile until at least 4 months of age when sperm appear in the ejaculate (Dziuk, 1977). Many factors, both genetic and environmental, influence the attainment of puberty in boars.

Genetic

Conflicting evidence exists relative to possible genetic effects on testicular development and attainment of puberty. Selection has resulted in increased testicular weight in mice (Islam et al., 1976). Differences have been noted between (Lunstra et al., 1978; Fields et al., 1979) and within (Swanson et al., 1971) breeds of beef bulls relative to rate of testicular development and attainment of puberty. In contrast, Wolf et al. (1965) observed no differences between Angus and Hereford bulls for age at first sperm production, first motile sperm production or first ejaculate produced containing at least 50 X 10^6 total sperm with 10% motile cells. Inbred lines of boars attain puberty at different ages (Warnick et al., 1949; Wiggins et al., 1951). Eden et al. (1978) found that prenatal factors accounted for 18% of the variance in testicular weight of boars at 168 days of age, suggesting possible important genetic influences. When purebred Duroc and Hampshire boars were compared, testicular weights and

sperm numbers were similar (Wilson et al., 1977). Also, sperm output was similar for Yorkshire and Lacombe boars, but ejaculation time was significantly longer for the Lacombe boars (Swierstra and Rahnefeld, 1967).

Environment

In a limited study, dietary restriction did not significantly influence age at puberty in boars, although there was a definite trend for the restricted boars to be older at puberty as measured by age at first mounting an estrous gilt and ejaculating semen containing spermatozoa (Dutt and Barnhart, 1959). Furthermore, restriction of dietary protein did not significantly affect pituitary gonadotropin content or reproductive organ weight in boars (Althen et al., 1974).

Confinement rearing of boars did not appear to influence sexual development (Ebenshade et al., 1979). However, Thomas et al. (1979) indicated that boars housed outdoors on earth lots reached puberty, as evidenced by age at first mounting an estrous gilt, earlier than did boars housed in confinement on concrete. Restriction of visual and physical contact with other pigs during very early development (3 to 12 weeks of age) permanently retards normal sexual behavior in boars (Hemsworth et al., 1977; Hemsworth et al., 1978). Boars reared in groups reached puberty younger than boars reared alone and boars reared together with females reached puberty at about the

same age as those reared in all male groups (Thomas et al., 1979). Hemsworth et al. (1977) also found that boars reared in groups with females or all male groups had similar sexual behavior.

Increasing the daily photoperiod will reduce the age at first successful semen collection from boars (Mahone, 1979). Minton et al. (1980) observed that crossbred boars exposed to a longer photoperiod had increased testicular endocrine function at 170 days of age. Boars exposed to 16 hr of light daily had greater average serum testosterone concentrations, increased areas under 12 hour testosterone profiles, increased height of testosterone secretory spikes and more testosterone secretory spikes per 12 hour sampling period than boars exposed to 8 hr of light.

Factors Affecting Puberty in Gilts

Genetic

Purebred lines of gilts differ with regard to age at first estrus (Warnick et al., 1949; Warnick et al., 1951; Clark et al., 1970; Christenson and Young, 1978). Thus, genetics greatly influences endocrine function in gilts.

Environment

Environmental factors have a marked impact on puberty (age at first estrus) in gilts. Fall born gilts are generally younger at puberty than spring born gilts

(Wiggins et al., 1950; Gossett and Sorensen, 1959; Zimmerman et al., 1960; Mavrogenis and Robison, 1976) however, Hutchens et al. (1978) suggested just the opposite, that spring born gilts are younger at puberty than fall born gilts. The part of the season in which the gilt is born (early vs late) might influence the age at puberty because seasonal effects are related to temperature, duration of photoperiod or other environmental factors. Tethering (Jensen et al., 1970) and confinement (Rampacek and Kraeling, 1978; Hoagland et al., 1979) tend to reduce the percentage of gilts which begin estrous cycles by a given age. Complete darkness may decrease the age to puberty in gilts (Dufour and Bernard, 1968), however, Hacker et al. (1974) and Ntunde et al. (1979) found that complete darkness, when compared to other photoperiods of various duration, increased the age at puberty in gilts. Presence of a boar tends to decrease age at puberty in gilts (Brooks and Cole, 1970; Hughes and Cole, 1976).

Nutritional regime during growth may influence the age at puberty in gilts. Full-fed gilts reach puberty at a younger age than their limit-fed counterparts (Robertson et al., 1951; Zimmerman et al., 1960). Limiting energy intake tends to increase the age at first estrus (Haines et al., 1959; Goode et al., 1960; O'Bannon et al., 1966). However, Aherne et al. (1976) found that, if energy was restricted to 85% of free choice, age to puberty was decreased. Other studies found no relationship between energy

intake and age at puberty (Gossett and Sorensen, 1959; Friend, 1977), probably because the different studies restrict energy in different ways and to varying degrees.

Restriction of either protein or amino acids in the diet generally causes a delay in puberal attainment (Friend, 1973; Cunningham et al., 1974; Friend, 1976). However, Friend (1977) has indicated no difference for age at puberty between gilts fed different levels of purified soybean protein. Age appears to influence puberty more than does body weight, though both have an influence.

Testicular Development of Boars

Marked development of the germinal epithelium in boars is first noted at about 84 days of age (Phillips and Andrews, 1936) and appearance of spermatozoa in the seminiferous tubules occurs at about 140 to 160 days of age (Phillips and Zeller, 1943; McFee and Eblen, 1967). Similarly, Hauser et al. (1952) found the first appearance of primary spermatocytes, secondary spermatocytes and spermatozoa in boars at about 90, 130 and 165 days of age, respectively. Seminiferous tubular and rapid testicular growth commences at about 100 to 140 days of age (Phillips and Zeller, 1943; McFee and Eblen, 1967), and testicular growth continues at a fairly constant rate until about 280 days of age (Phillips and Zeller, 1943). Testicular development is more closely associated with body weight

than with age (Green and Winters, 1944). Eden et al., (1978) found that testicular length and width of boars increased with age from 56 to 168 days of age.

Plasma luteinizing hormone (LH) (Colenbrander et al., 1977) and testosterone (Colenbrander et al., 1978) concentrations are increased until 2 to 3 weeks of age, then concentrations of both hormones decrease. These changes are comparable with the changes which occur with age in the morphological differentiation (Van Straaten and Wensing, 1978) and testosterone concentrations (Booth, 1975) of the boar testis.

Leydig cells, the steroid hormone producing cells of the testis, develop in a stage-like fashion and cells with characteristics similar to those in adult boars appear at about 13 weeks of age (Van Straaten and Wensing, 1978). Systemic testosterone concentrations increase rapidly at about 18 weeks of age (Gray et al., 1971; Colenbrander et al., 1978). Meusey-Dessolle (1975) noted that plasma testosterone in boars increased at a later age (27 weeks). Plasma testosterone concentration then continued to increase to 44 weeks of age.

Similarly, rapid increases in plasma testosterone occur in bulls (Macmillan and Hafs, 1968; Rawlings et al., 1972; Lund-Larsen et al., 1977; McCarthy et al., 1979), man (August et al., 1972), rats (Lee et al., 1975; Ketelslegers et al., 1978) and rams (Crim and Geschwind, 1972) at about

the age of the onset of observed behavioral and functional puberty.

Luteinizing Hormone and Testosterone in Males

Temporal Relationship

Frequent blood sampling reveals increases in plasma LH concentrations or "spikes" of LH, followed by increases in testosterone in mature bulls (Katangole et al., 1971; Smith et al., 1973; Karg et al., 1976; Minton, 1980) and rams (Sanford et al., 1974; Schanbacher and Ford, 1976; Foster et al., 1978). Number of LH spikes per 24 hour period in bulls ranges from 3 to 10 (Katangole et al., 1971; Smith et al., 1973; Minton, 1980). Percentage of plasma testosterone increases that are preceded by an increase in plasma LH in bulls ranges from 64 to 100 percent (Katangole et al., 1971; Smith et al., 1973; Karg et al., 1976, Minton, 1980). Significant positive correlations exist between LH concentration in a given blood sample and testosterone concentration in a blood sample taken one hour later ($r = 0.34$, Welsh and Johnson, 1978; 0.64, Minton, 1980). In frequently sampled rams, each increase in plasma testosterone was preceded by an increase in plasma LH (Sanford et al., 1974; Schanbacher and Ford, 1976; Foster et al., 1978) and similar to bulls, the time between the LH increase and the subsequent testosterone increase was about 1 hour

(Schanbacher and Ford, 1976). These data strongly suggest a positive temporal relationship between LH and testosterone in bulls and rams.

When yearling Yorkshire boars were sampled at half-hour intervals for 24 hours, plasma testosterone concentrations ranged from 0.6 ng to 11.5 ng/ml with an average of 2.4 testosterone increases within a 24 hour period (Brock and Wettemann, 1976). Similarly, plasma testosterone varied from less than 1 ng/ml to about 3 ng/ml with about 4 increases greater than 2 standard deviations above the mean, per 48 hour period in 3 puberal boars (Claus and Gimenez, 1977). Also, half-hourly samples from 18 puberal boars revealed an average of 2.9 secretory "spikes" of testosterone per 24 hour period (Kattesh et al., 1979b). Kattesh et al. (1979a) found considerable variation within and among puberal boars for plasma testosterone concentrations when blood samples were collected at half-hour intervals.

A positive relationship between LH and testosterone in boars is indicated by significant positive correlation coefficients of 0.22 (Welsh and Johnson, 1978) and 0.26 (Welsh and Johnson, 1979) between LH concentration in a given blood sample and the testosterone concentration in a blood sample taken one hour later. In contrast to the aforementioned studies, half-hourly blood samples from mature male miniature pigs revealed no significant alterations or relationships in either plasma LH or testosterone

concentrations (Ellendorff, 1975). Perhaps endocrine function is somewhat different in miniature boars than in domestic boars.

Normal hypophyseal-testicular function in the puberal and mature boar is characterized by variations in systemic concentrations of LH and testosterone during the course of a day. In boars, as in most species, it appears that there is a positive temporal relationship between plasma LH and testosterone concentrations. The physiological significance of such pulsatile hormone secretions to the reproductive or body processes is yet to be determined.

Factors Affecting LH and Testosterone

The anterior lobe of the pituitary synthesizes LH in mammals. Although there is no direct innervation of the anterior lobe of the pituitary gland, it is controlled by hypothalamic regulatory peptides synthesized by the hypothalmus and transported to the anterior lobe by portal vessels. By extraction of thousands of ovine or porcine hypothalmi, a substance was isolated that caused synthesis and release of LH from the anterior lobe of the pituitary and was named Gonadotropin Releasing Hormone (GnRH). Luteinizing hormone released after GnRH stimulation causes androgen secretion from the interstitial cells of the testes in boars (Brock and Wettemann, 1977; Welsh and Johnson, 1979) and bulls (Mongkonpunya et al., 1974;

Mongkonpunya et al., 1975; Bindon et. al., 1976; Thibier, 1976; Schanbacher and Echternkamp, 1978; Minton, 1980).

Brock and Wettemann (1976) found that infusion of mature Yorkshire boars with 1 mg of LH caused plasma testosterone concentrations to increase from 3.2 ng/ml to 25.5 ng/ml in one hour. Plasma testosterone concentrations remained above pre-treatment values for 6 hours. A similar response to LH treatment has been observed in bulls (Smith et al., 1973; Schanbacher, 1979).

Testosterone exerts a negative "feedback" on LH release. If boars are castrated, plasma LH concentrations are consistently greater than in intact boars (Ford and Schanbacher, 1977).

Testosterone is responsible for normal sexual behavior in the boar. Evidence of this is the variable disappearance of libido from sexually experienced boars after castration and the restoration of "normal" libido through testosterone injection (Pickett et al., 1967). Sexual behavior, but not testicular development, can be induced in pre-puberal boars by injection of LH, FSH or testosterone (Ellendorff et al., 1970).

Influence of GnRH on Plasma LH and Testosterone Concentrations

Under normal conditions, GnRH from the hypothalmus is probably the major factor controlling LH release in mammals. Injection of synthetic GnRH resulted in elevated

plasma LH and subsequently testosterone in puberal and post-puberal bulls (Mongkonpunya et al., 1974; Mongkonpunya et al., 1975; Bindon et al., 1976; Thibier, 1976; Schanbacher and Echternkamp, 1978; Minton, 1980). Similarly, treatment of puberal and adult male miniature swine with GnRH results in increased plasma LH concentrations which were 5 times greater than the pre-treatment concentrations within 5 to 15 minutes after treatment (Pomerantz et al., 1974). Plasma LH concentrations returned to basal values within two hours post-injection. Plasma LH and testosterone concentrations were increased after crossbred boars were injected with 50, 100 or 200 μg of GnRH (Brock and Wettemann, 1977). Maximum plasma testosterone concentrations occurred 1.5 to 2 hours after GnRH treatment and concentrations were similar to pre-treatment values by 6 hours post-injection. Similarly, significant increases in plasma LH and testosterone were noted by 30 minutes after intravenous infusion of 200 μg of GnRH in 8 month old Yorkshire boars (Welsh and Johnson, 1979) and maximum testosterone concentrations occurred between 1 and 2 hours post-infusion.

Coefficients of variation (CV) for serum testosterone in boars were reduced after GnRH treatment (Brock and Wettemann, 1977). Before treatment CV were about 100%, and CV were reduced to 60% within 3 hours after treatment.

The positive relationship between LH and testosterone in boars is similar to that in other mammals. Luteinizing

hormone from the pituitary is controlled by hypothalmic GnRH and androgens have "negative feedback" effects on pituitary secretion of LH. In addition, treatment of boars with GnRH results in increased plasma LH and testosterone concentrations of similar magnitudes to those observed in normal boars. Treatment with GnRH may also reduce CV for systemic testosterone concentrations.

CHAPTER III

MATERIALS AND METHODS

Animal Management

Purebred and two-breed cross boars of Duroc, Landrace, Spot and Yorkshire breeding that were raised at the Swine Research Farm at Stillwater, were used in this study. Testicular characteristics were obtained from 136 boars (Table I; Table XXIII, Appendix) castrated at 218 ± 6 days of age and 113 ± 13 kg body weight during 4 seasons (Spring 1977, Fall, 1977, Fall 1978 and Spring 1979). Spring season was March, April and May, and Fall season was September, October and November. Blood samples were obtained from 139 boars (Table I; Table XXIV, Appendix) averaging 218 ± 5 days of age during 5 seasons (Spring 1977, Fall 1977, Spring 1978, Fall 1978 and Spring 1979). A total of 120 boars were both bled and castrated. Boars were progeny of 8 to 10 different sires of each of the four pure breeds (Table XXV, Appendix).

Boars were obtained from sows farrowed and maintained in confinement until weaned at 6 weeks of age. After weaning, boars were housed in an open front building with a solid concrete floor (4 - 6 boars per pen) and fed a 14% crude protein, corn, milo and soybean meal ration ad libitum

TABLE I

EXPERIMENTAL ANIMALS

Breed Type		No. Castrated	No. Bled
Duroc (D)		13	14
Landrace (L)		9	10
Spot (S)		12	12
Yorkshire (Y)		10	9
	Purebred	44	45
DL		17	19
DS		16	17
DY		15	16
LS		14	13
LY		14	14
SY		16	15
	Crossbred	92	94
Total		136	139

until about 5.5 months of age. Then boars were managed in dirt lots in large groups (10 - 15 boars per lot). Boars were assigned to castration and bleeding groups weekly as they became 7 months of age and were transported approximately 5 kilometers from the Swine Research Farm to the Nutrition-Physiology Research Center (NPRC). At the NPRC, 2 to 4 boars were maintained in total confinement in each slatted floor pen (2.3 X 4 m) and exposed to ambient temperatures between 20 and 26 C. Boars were fed 2 kg of a 14% crude protein ration once daily and water was provided ad libitum.

Blood Sampling

Five days following arrival at the NPRC, boars were injected intramuscularly with 200 μg of Gonadotropin Releasing Hormone (GnRH; Abbott Laboratories), and 25 ml blood samples were obtained by puncture of the anterior vena cava or jugular vein just prior to and at 1, 2, 3 and 4 hours after GnRH treatment. Blood samples were placed in 50 ml polyethylene tubes, cooled in an ice water bath immediately after collection, capped and stored for 24 to 36 hours at 4 C. Blood samples were then centrifuged and serum was decanted into 12 ml plastic vials for storage at -20 C until assayed for luteinizing hormone (LH) and testosterone.

Sampling of Testes

The day after blood samples were collected, boars were anesthetized with Sodium Thiopentothal and castrated. The right testis from each boar was retained, placed in a plastic bag and immediately put on ice and dissected within 36 hours. Body weights were obtained at the time of castration.

Determination of Testicular and Epididymidal Sperm Numbers

Epididymides were dissected from the testes and vas deferns were trimmed to approximately 6 cm in length. Weights were obtained for testes, capita-corpora and caudae epididymides after removal of excess connective tissue. Twenty grams of testicular parenchymae, the entire capita-corpora epididymides and the entire caudae epididymides were then minced and homogenized individually in a Waring Blender for approximately 2 minutes in 200, 250 and 250 ml, respectively, of saline-Triton-Merthiolate (STM) solution (0.9% NaCl containing 0.05% (v/v) triton X-100 with 100 ppm merthiolate; Amann and Lambiase, 1969). Homogenates were strained through 3 layers of cheese cloth and approximately 50 ml aliquots were saved for further dilution with STM. Generally, testicular homogenates were diluted 1:5 in STM, and epididymidal homogenates were diluted 1:25. These dilutions resulted in approximately 50 to 200 sperm in the

hemocytometer counting chamber. Dilutions were kept at 4 C until duplicate counts were obtained by two technicians within ten days after homogenization. Sperm cells were counted (Kirton et al., 1967) using a hemocytometer with phase contrast microscopy and total sperm per tissue was calculated.

Hormone Quantification

Blood serum samples were assayed for testosterone and LH concentration at random within season.

LH

Serum LH concentrations were determined by a radioimmunoassay similar to that described by Niswender et al. (1970) using a specific antisera (No. 566, supplied by G. D. Niswender) to porcine LH. Validation of this assay was reported (Hallford et al., 1975; Hoagland, 1980). Barrow serum was diluted with phosphate buffered saline plus 1% gel and used for standard curves. Standard tubes contained 0, .016, .032, .065, .130, .251, .502, 1.012, 1.620 and 2.429 ng of LH based on purified porcine LH (LER-786-3). The following internal standards were quantified in each assay: pre-GnRH barrow (3.6 ± .4 ng/ml, n = 7), post-GnRH barrow #1 (8.1 ± .5 ng/ml, n = 5) and post-GnRH barrow #2 (17.0 ± 1.7 ng/ml, n = 4). When 0.5 ml of pre-GnRH barrow was mixed with 0.5 ml of post-GnRH barrow #1, the

concentration was 5.8 ± .6 ng/ml, (n = 5). The between assay coefficient of variation was 9.0 percent.

Testosterone

Serum testosterone concentrations were determined by the radioimmunoassay described by Wettemann and Desjardins (1979). Chloroform was substituted for benzene for extraction. Extraction efficiencies (n = 10) for hexane:benzene (2:1) and hexane:chloroform (2:1) were 79.1 ± 1.9 and 97.5 ± 1.1 percent, respectively. The intra-class correlation between serum samples assayed after extraction with either hexane:benzene (2:1) or hexane:chloroform (2:1) was 0.98 ($\bar{x}$ = 2.3, n = 16; $\bar{x}$ = 2.1; n = 16). Barrow serum and/or charcoal-stripped barrow serum plus known quantities of testosterone were quantified in each assay. Barrow serum was "stripped" by the addition of 5 mg charcoal per ml of serum. The suspension was mixed at room temperature for 1 min at 5 min intervals for 30 min. Then the suspension was centrifuged at 5,000 X g for 20 min and the serum was decanted. The above procedure was repeated once to prepare the "stripped" serum. Barrow serum contained 0.2 ± 0.01 (n = 19) ng/ml of testosterone. Addition of 0, 2 or 10 ng of testosterone to 1 ml "stripped" serum samples resulted in 0.2 ± 0.02 (n = 8), 2.2 ± .1 (n = 21) and 9.6 ± .2 (n = 27) ng/ml, respectively. The between assay coefficient of variation was 5%.

Statistical Analysis

Serum hormone quantities at each hour and testicular and epididymidal characteristics were analyzed by least squares procedures. The model was:

$$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + e_{ijk}$$

where Y_{ijk} = the observed trait of the k^{th} boar from the i^{th} season and the j^{th} breed type, μ is the overall mean; A_i = fixed effect of the i^{th} season; B_j = fixed effect of the j^{th} breed type; AB_{ij} represents the breed type by season interaction and e_{ijk} is the random effect associated with the ijk^{th} observation. Correlations among traits were obtained from within season and breed type using corrected sums of squares and cross products and pooled across subclasses. Differences between mean pairs were tested for least significant difference.

CHAPTER IV

RESULTS AND DISCUSSION

Influence of Season on Testicular and Epididymidal Characteristics

Testicular and epididymidal characteristics were determined during four seasons from a total of 136 boars at 218 ± 6 days of age (Table II). Similar to previous studies (Wilson et al., 1977; Neely et al., 1979) crossbred boars grew more rapidly and were heavier ($P < .05$) at castration than purebred boars (115 ± 1.4 and 108 ± 1.7 kg, respectively).

Season influenced ($P < .01$) capita-corpora epididymidal weight, total testicular sperm, total capita-corpora epididymidal sperm and total caudae epididymidal sperm (Table II). Wilson et al. (1977) and Eden et al. (1978) also noted significant season effects on some testicular and epididymidal characteristics of 7.5 and 5.5 month old boars, respectively. Because data collection in the present study encompassed 2.5 years, difference between technicians is confounded with season and might account for some of the season effects. Although season effects were noted, none of the breed by season interactions were significant.

TABLE II

INFLUENCE OF SEASON ON TESTICULAR CHARACTERISTICS OF BOARS

	Season				
	1	2	3	4	$\bar{X}$
No. Boars	35	35	32	34	136
TW[c](G)	271.8 ± 11.3[a]	274.5 ± 11.0	276.4 ± 8.6	283.4 ± 12.1	276.5 ± 5.0
TS[d](X 10^9)[b]	38.2 ± 4.0	31.2 ± 2.2	28.8 ± 2.7	25.7 ± 3.0	31.0 ± 1.5
CCEW[e](G)[b]	33.4 ± 1.6	33.1 ± 1.4	27.0 ± 1.1	30.0 ± 1.3	30.5 ± 0.6
CCES[f](X 10^9)[b]	32.0 ± 2.6	32.2 ± 2.6	19.8 ± 2.6	20.4 ± 2.5	26.3 ± 1.2
CEW[g](G)	32.2 ± 1.5	35.1 ± 1.4	35.1 ± 1.1	35.3 ± 1.5	34.4 ± 0.7
CCES[h](X10^9)[b]	57.3 ± 4.7	57.7 ± 4.4	41.9 ± 4.1	44.0 ± 5.2	50.4 ± 2.2

[a]Mean ± standard error of mean

[b]Significant effect of season ($P < .01$)

[c]Testicular weight

[d]Testicular sperm number

[e]Capita-corpora epididymidal weight

[f]Capita-corpora epididymidal sperm number

[g]Caudae epididymidal weight

[h]Caudae epididymidal sperm number

Influence of Breed on Testicular Characteristics

Breed of boar influenced testicular weights ($P < .01$; Table III). Breed type means for testicular weights which were significantly ($P < .05$) different were: DD vs DS, DY, LL and LY; SS vs DY and LY; SY vs DD, DL, LS, SS and YY; YY vs DS, DY and LY. Crossbred boars had 19% heavier testes ($P < .01$) than purebred boars (291.5 ± 6.4 and 245.1 ± 8.3 gm, respectively). Similarly, Wilson et al. (1977) found that Duroc X Hampshire crossbred boars had 16% heavier testes than purebred boars at 7.5 months of age. Duroc X Yorkshire crossbred boars had 28% heavier testes than purebred boars at 5.5 months of age (Neely et al., 1979). Hauser et al. (1952) also indicated that crossbred boars had about 30% heavier testes than purebred boars at the same age. The overall average testicular weight in the present study was 276 ± 5.0 grams, which is slightly less than the 349.1 and 389.1 grams for 11 month old Yorkshire and Lacombe boars, respectively (Swierstra, 1968). Wilson et al. (1977) found that the testes of Hampshire and Duroc purebred and crossbred boars at 7.5 months averaged 316.6 grams, but at 5.5 months of age the testes of boars weighed only 167 grams (Eden et al., 1978).

Although breed type was not a significant source of variation for total testicular sperm, it approached significance ($P = .12$, Table III). Crossbred boars had 33.7 ± 2.0 X 10^9 testicular sperm cells which was 33% greater

TABLE III

INFLUENCE OF BREED ON TESTICULAR CHARACTERISTICS OF BOARS

Breed Type	Testicular	
	Weight[a] (G)	Total Sperm ($X 10^9$)
DD[b]	229.5 ± 15.5[c]	21.9 ± 2.8
LL	284.4 ± 16.9	30.0 ± 5.8
SS	240.4 ± 16.9	27.1 ± 5.1
YY	235.5 ± 13.9	23.9 ± 5.5
DL	272.3 ± 19.5	32.4 ± 7.8
DS	287.3 ± 17.2	31.8 ± 4.1
DY	306.4 ± 12.3	39.9 ± 2.7
LS	269.9 ± 16.0	28.5 ± 4.3
LY	293.4 ± 12.2	35.2 ± 3.4
SY	319.4 ± 11.9	34.5 ± 4.0
Purebred Mean	243.1 ± 8.3	25.4 ± 2.3
Crossbred Mean	291.5 ± 6.4	33.7 ± 2.0
Crossbred - Purebred	46.4 ± 10.8[d]	8.3 ± 3.2[d]

[a]Significant effect of breed type ($P < .01$)

[b]D = Duroc; L = Landrace; S = Spot; Y = Yorkshire

[c]Mean ± Standard error of mean or mean difference

[d]$P < .01$

($P < .01$) than the $25.4 \pm 2.3 \times 10^9$ cells for purebred boars. Similarly, Wilson et al. (1977) and Neely et al. (1979) observed that crossbred boars had 25 and 34% more testicular sperm, respectively, than purebred boars at 7.5 and 5.5 months of age. Over all breeds, total testicular sperm averaged $31.0 \pm 1.5 \times 10^9$ sperm per testis in the present study. This value is very similar to the 28.7 ± 1.4 and $36.0 \pm 1.6 \times 10^9$ sperm for purebred and crossbred boars at 7.5 months of age (Wilson et al., 1977), but less than the value of $50.2 \pm 9.0 \times 10^9$ total testicular sperm for yearling Yorkshire boars (Wettemann et al., 1976). As might be expected, boars at 5.5 months of age only had $9.6 \pm 0.7 \times 10^9$ total testicular sperm (Eden et al., 1978). Testicular weights and sperm numbers in the present study, in comparison with experiments by others with boars at different ages, suggests that these boars had not yet reached sexual maturity.

Influence of Breed on Capita-Corpora Epididymidal Characteristics

Breed type was a significant source of variation for both capita-corpora weight ($P < .01$) and sperm numbers ($P < .05$, Table IV). Breed type means which were significantly different ($P < .05$) for capita-corpora weight were: DY vs DD, DL, LL, LS, LY, SS, SY and YY; SY vs LS, SS and YY. Crossbred boars had 14% heavier ($P < .01$) capita-corpora epididymides than purebred boars ($31.7 \pm .9$ vs

TABLE IV

INFLUENCE OF BREED ON CAPITA-CORPORA EPIDIDYMIDAL CHARACTERISTICS OF BOARS

Breed Type	Capita-Corpora Epididymidal	
	Weight[a] (G)	Total Sperm[b] (X 10^9)
DD[c]	28.8 ± 2.6[d]	19.4 ± 3.4
LL	29.0 ± 2.0	25.1 ± 4.8
SS	27.4 ± 2.2	23.1 ± 4.9
YY	26.3 ± 1.2	15.7 ± 3.8
DL	29.5 ± 2.3	22.1 ± 3.7
DS	31.7 ± 2.3	30.6 ± 4.1
DY	36.8 ± 2.5	31.6 ± 3.4
LS	27.9 ± 2.5	27.0 ± 5.7
LY	30.3 ± 1.6	30.4 ± 3.5
SY	33.7 ± 1.4	32.5 ± 4.5
Purebred Mean	27.9 ± 1.1	20.8 ± 2.1
Crossbred Mean	31.7 ± 0.9	28.9 ± 1.7
Crossbred - Purebred	3.8 ± 1.4[e]	8.1 ± 2.7[e]

[a]Significant effect of breed type ($P < .01$)

[b]Significant effect of breed type ($P < .05$)

[c]D = Duroc; L = Landrace; S = Spot; Y = Yorkshire

[d]Mean ± standard error of mean or mean difference

[e]$P < .01$

27.9 ± 1.1 grams). Similarly, Hauser et al. (1952) indicated that crossbred boars had 27% heavier epididymides than purebred boars of the same age. Crossbred and purebred Duroc and Hampshire boars, however, had similar capita-corpora epididymidal weights when castrated at 7.5 months of age (Wilson et al., 1977).

Breed group means which were significantly different ($P < .05$) for capita-corpora epididymidal sperm numbers were: DD vs DS, DY, LY and SY; DL vs DY and SY; YY vs DS, DY, LY and SY. Crossbred boars had 39% more ($P < .01$) total capita-corpora epididymidal sperm than purebred boars (28.9 ± 1.7 vs 20.8 ± 2.1 X 10^9 sperm). Similarly, Neely et al. (1979) found large positive heterosis effects for total sperm in the capita epididymides of Duroc and Yorkshire boars at 5.5 months of age. In contrast, 7.5 month old purebred and crossbred boars (Duroc and Hampshire) had similar numbers of sperm in the capita-corpora epididymides (Wilson et al., 1977).

Over all breeds, the capita-corpora epididymides weighed 30.5 ± 0.6 grams and contained 26.3 ± 1.2 X 10^9 sperm. Wilson et al. (1977) found that capita-corpora epididymides of 7.5 month old boars were slightly heavier (49.3 ± 6.1 grams) but contained similar total sperm (25.4 ± 1.6 X 10^9).

Influence of Breed on Caudae Epididymidal Characteristics

Breed type significantly influenced both caudae epididymidal weight ($P < .01$) and sperm number ($P < .05$; Table V). Breed group means which were different ($P < .05$) for caudae epididymidal weight were: DY vs DD, LL, LS, LY and SY; SS vs DD, DL, DS, DY, LL and SY; YY vs DL, DS and DY. On the average, crossbred boars had caudae epididymides that were 15% heavier ($P < .01$) than purebred boars (36.0 ± 0.8 and 31.2 ± 1.2 gm, respectively). Hauser et al. (1952) also observed that crossbred boars had heavier caudae epididymides than purebred boars at the same age, and Wilson et al. (1977) indicated that crossbred boars had 8% heavier caudae epididymides than purebred boars at 7.5 months of age. In the present study caudae epididymides averaged 34.4 ± 0.7 grams, which is slightly less than the 43.0 ± 2.5 grams for 7.5 month old boars found by Wilson et al. (1977). At 5.5 months of age, the caudae epididymides only weighed 12.2 ± .3 grams (Eden et al., 1978).

Breed type means which were significantly different ($P < .05$) for caudae epididymidal sperm numbers were: SS vs DY; YY vs DS, DY, LL and SY. Crossbred boars had 22% more ($P < .05$) total caudae epididymidal sperm than purebred boars (53.6 ± 2.9 vs 43.8 ± 3.8 X 10^9). In contrast, Wilson et al. (1977) found that crossbred and purebred Duroc and Hampshire boars had similar caudae epididymidal sperm numbers, whereas, Neely et al. (1979) observed

TABLE V

INFLUENCE OF BREED ON CAUDAE EPIDIDYMIDAL CHARACTERISTICS OF BOARS

Breed Type	Caudae Epididymidal	
	Weight[a] (G)	Total Sperm[a] (X 10^9)
DD[b]	33.4 ± 2.4[c]	49.9 ± 7.6
LL	34.6 ± 2.8	56.3 ± 8.6
SS	27.3 ± 2.3	39.0 ± 6.7
YY	29.9 ± 1.8	30.2 ± 6.1
DL	36.2 ± 2.2	47.7 ± 8.0
DS	36.6 ± 2.2	55.8 ± 7.7
DY	41.4 ± 1.3	64.0 ± 5.7
LS	32.7 ± 1.9	46.6 ± 9.1
LY	32.8 ± 1.9	48.6 ± 5.5
SY	35.6 ± 1.5	58.7 ± 6.5
Purebred Mean	31.2 ± 1.2	43.8 ± 3.8
Crossbred Mean	36.0 ± 0.8	53.6 ± 2.9
Crossbred - Purebred	4.8 ± 1.4[d]	9.8 ± 4.9[e]

[a]Significant effect of breed type ($P < .01$)

[b]D = Duroc; L = Landrace; S = Spot; Y = Yorkshire

[c]Mean ± Standard error of mean or mean difference

[d]$P < .01$

[e]$P < .05$

negative heterosis for caudae epididymidal sperm number in Duroc and Yorkshire boars at 5.5 months of age. Since caudae epididymidal sperm are the cells which are awaiting ejaculation, frequency of ejaculation might influence the number of sperm present in the caudae epididymides at any given time. The boars in the present study were managed in small groups and were semi-isolated from other pigs; this management scheme might have reduced the incidence of ejaculation by masturbation. In contrast, prior to castration, Wilson et al. (1977) managed boars in groups of 10 to 12 which might have allowed more social interaction and ejaculation. The boars in Wilson et al.'s (1977) experiment were also in physical and visual contact with more pigs than in the present study. Management scheme prior to castration was not described by Neely et al. (1979), however, it was stated that it was felt that the crossbred boars in the study may have been masturbating more frequently and ejaculating more sperm per ejaculate than the purebreds. The increased sperm loss by ejaculation from the epididymis could account for the apparent negative heterosis for caudae epididymidal sperm. The differences observed in caudae epididymidal sperm in the various studies could also be due to age at castration, different breed combinations or other management factors.

Caudal sperm numbers for all breeds averaged 50.4 X 10^9 in the present study, which was greater than the 41.3 ± 3.3 X 10^9 for 7.5 month old boars (Wilson et al., 1977) and

$2.2 \pm .3 \times 10^9$ for 5.5 month old boars (Eden et al., 1978). Age probably accounts for the lower values in 5.5 month old boars. The lower number of caudae epididymidal sperm observed by Wilson et al. (1977) could be related to the reduced sperm numbers in purebred Hampshire boars when compared to the other breed groups.

Breed of sire influenced capita-corpora epididymidal weight ($P < .05$; Table XVI, Appendix), and breed of dam influenced body weight and caudae epididymidal weight ($P < .05$; Table XVII, Appendix). Similarly, breed of sire influenced testicular, capita-corpora and caudae epididymidal weights in 7.5 month old boars (Wilson et al., 1977). In addition, breed of dam significantly influenced average daily gain of barrows and gilts (Johnson et al., 1973; Young et al., 1976b) and individual pig weight at 140 days of age (Nelson and Robison, 1976).

Correlations Among Testicular and Epididymidal Characteristics

Partial correlation coefficients among testicular and epididymidal characteristics are listed in Table VI. All of the coefficients were significant ($P < .05$) except those between body weight and testicular, capita-corpora and caudae epididymidal sperm numbers ($P > .10$). Body weight was, however, significantly correlated ($P < .01$) with testicular, capita-corpora and caudae epididymidal weights

TABLE VI

PARTIAL CORRELATION COEFFICIENTS FOR TESTICULAR AND EPIDIDYMIDAL CHARACTERISTICS OF BOARS

	TW[b]	CCEW[c]	CEW[d]	TS[e]	CCES[f]	CES[g]
BW[a]	.32	.34	.30	.10[h]	.14[h]	.14[h]
TW[b]	---	.71	.66	.50	.53	.54
CCEW[c]	---	---	.65	.27	.58	.44
CEW[d]	---	---	---	.38	.47	.71
TS[e]	---	---	---	---	.45	.40
CCES[f]	---	---	---	---	---	.50

[a]Body weight
[b]Testicular weight
[c]Capita-corpora epididymidal weight
[d]Caudae epididymidal weight
[e]Testicular sperm number
[f]Capita-corpora epididymidal sperm number
[g]Caudae epididymidal sperm number
[h]$P > .05$, all other correlations are significant ($P < .05$)

(.32, .34 and .30, respectively). These data indicate that boars which were heavier at castration tended to have heavier testes and epididymides.

Correlations among the testicular and epididymidal characteristics were all significant and positive, and ranged from .27 to .71. In particular, testicular weight was correlated with capita-corpora and caudae epididymidal weights (.71 and .66, respectively, $P < .001$). Testicular weight was also correlated with testicular, capita-corpora and caudae epididymidal sperm numbers (.50, .53 and .54, respectively, $P < .001$). These data indicate that those boars with larger testes tended to have larger epididymides as well as more total sperm in the testes and epididymides. Similarly, Wilson et al. (1977) found significant positive correlations among testicular and epididymidal characteristics of 7.5 month old boars, with one exception: testicular weight and caput-corpora epididymidal weight were not significantly correlated. Testicular weights are also correlated ($r = .65$) with testicular sperm numbers in mature bulls (Almquist and Amann, 1961) and in mice ($r = .57$; Johnson and Eisen, 1975).

Simple correlations among testicular and epididymidal characteristics using breed type averages ranged from .56 to .90 (Table VII). In particular, testicular weight was significantly correlated with testicular sperm number, capita-corpora epididymidal weight, capita-corpora epididymidal sperm number, caudae epididymidal weight and caudae

TABLE VII

CORRELATIONS AMONG TESTICULAR AND EPIDIDYMIDAL CHARACTERISTICS OF BOARS USING BREED AVERAGES

	TW[b]	TS[c]	CCEW[d]	CCES[e]	CEW[f]	CES[g]
BW[a]	.62[h]	.56[h]	.77	.69	.66	.73
TW[b]	---	.90	.80	.90	.70	.78
TS[c]	---	---	.84	.84	.71	.69
CCEW[d]	---	---	---	.78	.86	.86
CCES[e]	---	---	---	---	.58[h]	.78
CEW[f]	---	---	---	---	---	.85

[a]Body weight
[b]Testicular weight
[c]Testicular sperm number
[d]Capita-corpora epididymidal weight
[e]Capita-corpora epididymidal sperm number
[f]Caudae epididymidal weight
[g]Caudae epididymidal sperm number
[h]$P > .05$, all other correlations are significant ($P < .05$)

epididymidal sperm number (0.90, $P < .001$; 0.80, $P < .01$; 0.90, $P < .001$; 0.70, $P < .05$; and .78, $P < .01$; respectively). These data indicate that those breed groups with heavier testes also tended to have heavier epididymides and more total sperm in both the testes and epididymides.

Testicular and epididymidal characteristics are in general agreement with those reported previously. Differences between studies may be related to the breeds of boars used. In the present study four breeds were used, whereas, most others evaluated only two breeds. When some of the breed type means are compared, it is revealed that if only two of the pure breeds had been evaluated, the comparison of crossbreds vs purebreds might have yielded quite different conclusions, because of the variation in heterosis between different crosses. Duroc, Landrace, Spot and Yorkshire breeds were chosen for this study because of availability, limited information on crossbred boars of these breeds, and the importance of these four breeds to successful and efficient commercial swine production.

Comparisons with other studies indicate that the boars in the present study were castrated before sexual maturity, but well after the onset of rapid testicular and sexual development. Mature boars have not been studied to determine breed differences for testicular characteristics, so whether or not differences exist similar to those observed in puberal boars is unknown. Crossbreeding may have its major influence on boars by decreasing the age to puberty.

Serum LH and Testosterone After GnRH Treatment

Average blood serum LH and testosterone concentrations for boars of all breed groups (n = 139) after treatment with 200 μg of GnRH are depicted in Figure 1. Luteinizing hormone conentration before GnRH treatment was 1.6 ± 0.1 ng/ml and increased 6-fold to a maximum value of 7.7 ± 0.3 ng/ml at 1 hour after injection. Then serum LH concentrations decreased linearly to 2.0 ± 0.1 ng/ml by 4 hours after treatment. Similarly, Brock and Wettemann (1977) found that LH concentration in crossbred boars increased from 5.7 ± 2.8 ng/ml before injection of 200 μg of GnRH to a maximum concentration of 48.0 ± 7.0 ng/ml within 1 hour. Then LH concentrations decreased to pre-treatment values within 5 hours after GnRH. Brock and Wettemann (1977) used a different LH standard (NIH-LH-S1) which was only 31% the potency of the standard (LER-786-3) that was used in the present study. This difference in the potency of the standard may account for the relatively smaller LH concentrations in the present study. Differences in breeds studied and management scheme, as well as bleeding method and frequency might also account for some differences in absolute LH quantities between the two studies. However, the magnitude (relative to basal) and duration of the increased LH response to 200 μg of GnRH were similar in the two experiments.

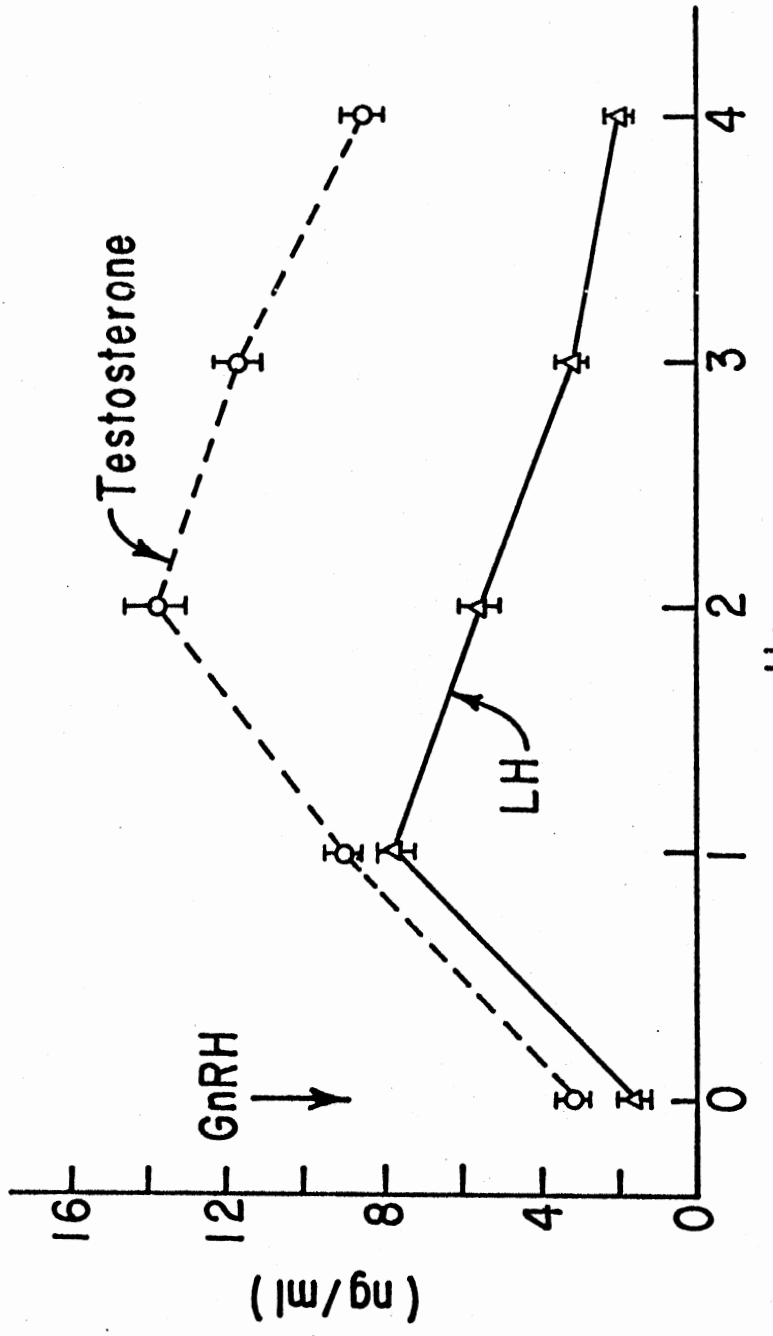

Figure 1. Serum Testosterone and LH in Boars After GnRH

Basal plasma LH concentrations in mature miniature boars averaged about 1 ng/ml, increased to maximum values within 20 minutes after GnRH injection, and were similar to pre-treatment concentrations by about 2 - 3 hours post-treatment (Pomerantz et al., 1974). Similarly, Welsh and Johnson (1979) found that serum LH in boars increased by 30 minutes after 200 μg GnRH treatment and reached maximum values between 1 and 2 hours post-treatment. Treatment with GnRH also causes increased plasma LH in bulls (Golter et al., 1973; Zolman et al., 1973; Schams et al., 1974; Mongkonpunya et al., 1974; Mongkonpunya et al., 1975; Bindon et al., 1976; Thibier, 1976; Schanbacher and Echternkamp, 1978;Schanbacher, 1979; Minton, 1980), rams (Hopkinson et al., 1974; Galloway and Pelletier, 1975; Lee et al., 1976; Lincoln, 1979), rats (Verjans and Eik-Nes, 1976; Bruni et al., 1977; Rush and Lipner, 1979), chimpanzees (Hobson and Fuller, 1977), rhesus monkeys (Toivola et al., 1978) and men (Kastin et al., 1969; Kastin et al., 1972; Haug and Torjesen, 1973; Rebar et al., 1973; Mecklenberg and Sherins, 1974; Schwarzstein et al., 1975; Bremner and Paulsen, 1977; Caminos-Torres et al., 1977; Nagayama, 1977; McNeil et al., 1979).

The average serum testosterone concentration (Figure 1) was 3.2 ± 0.2 ng/ml before treatment. Testosterone increased 3-fold to 8.9 ± 0.5 ng/ml by 1 hour after GnRH treatment, and attained a maximum concentration of 13.8 ± 0.8 ng/ml (4.5 times basal value) by 2 hr. Testosterone

concentrations then decreased to 11.7 ± 0.5 and 8.5 ± 0.4 ng/ml at 3 and 4 hours post-treatment. Similarly, when boars were infused with 200 μg of GnRH, serum testosterone increased from a pre-treatment concentration of 2.8 ± 0.3 ng/ml to a maximum of 13.7 ± 2.6 ng/ml (a 5-fold increase) at 2 hours post-treatment, and testosterone decreased to basal values by 6 hours after treatment (Brock and Wettemann, 1977). Welsh and Johnson (1979) also found that an intravenous infusion of 200 μg of GnRH caused increased serum testosterone in 8 month old boars. Similarly, GnRH treatment causes increases in plasma testosterone in bulls (Mongkonpunya et al., 1975; Bindon et al., 1976; Thibier, 1976; Schanbacher and Echternkamp, 1978; Schanbacher, 1979; Minton, 1980), rams (Lee et al., 1976; Lincoln, 1979), rats (Bruni et al., 1977), rhesus monkeys (Toivola et al., 1978) and men (Rowe et al., 1975; Schwarzstein et al., 1975; Bremner and Paulsen, 1977; Nagayama, 1977; McNeil, 1979).

The variation in serum LH relative to the mean (coefficient of variation) was similar at each time boars were sampled, however, GnRH appeared to slightly reduce the coefficient of variation in serum testosterone quantities (Table VIII). Similarly, GnRH treatment of boars managed in confinement in environmental chambers reduced the coefficient of variation in serum testosterone from about 100% (pre-treatment) to about 60% within 3 hours post-treatment (Brock and Wettemann, 1977).

TABLE VIII

COEFFICIENTS OF VARIATION[a] FOR SERUM LH AND TESTOSTERONE IN BOARS AFTER GnRH TREATMENT

Time After GnRH (hr)	LH	Testosterone
0	50	77
1	48	69
2	47	68
3	50	51
4	50	62

[a]CV = (Standard deviation/mean) X 100

Influence of Crossbreeding on Serum LH and Testosterone Response to GnRH Treatment

LH

Analysis of variance at each hour revealed a difference ($P < .05$) between crossbred and purebred boars for serum LH concentrations (Figure 2) only at 3 hours after treatment (3.3 ± 0.2 and 2.9 ± 0.2 ng/ml, respectively, for crossbred and purebred boars). Luteinizing hormone concentrations were slightly greater ($P > .10$) for crossbred than purebred boars at all other sampling times. These data suggest that crossbred boars may respond to GnRH treatment with slightly greater systemic LH quantities than purebreds at 7 months of age.

Testosterone

Serum testosterone response to GnRH treatment for purebred and crossbred boars is depicted in Figure 3. Analysis of variance at each hour revealed no differences ($P > .10$) for serum testosterone between crossbred and purebred boars prior to and during the first 3 hours after GnRH treatment. However, crossbred boars had greater ($P < .05$) serum testosterone concentrations at 4 hours after GnRH treatment (9.3 ± 0.7 vs 6.9 ± 0.7 ng/ml). This difference suggests that although crossbred and purebred boars have similar maximum testosterone concentrations after GnRH treatment, the

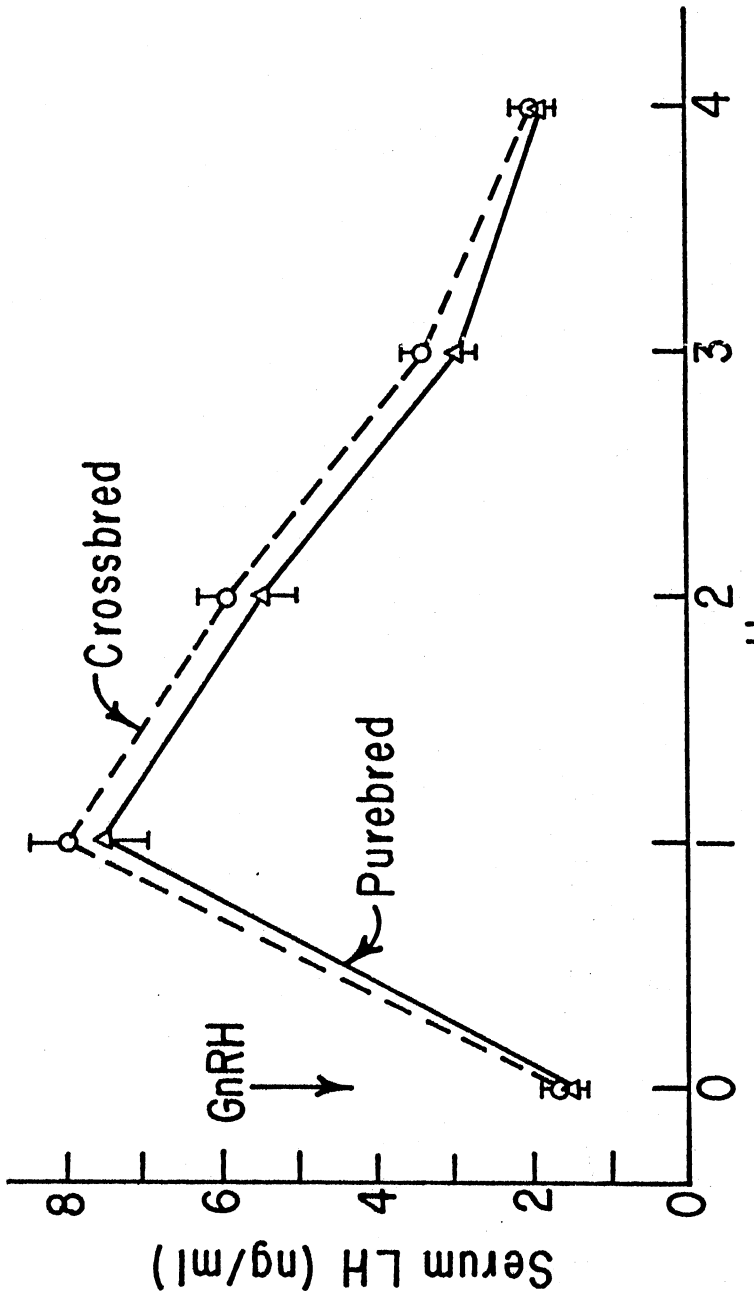

Figure 2. Serum LH in Boars After GnRH

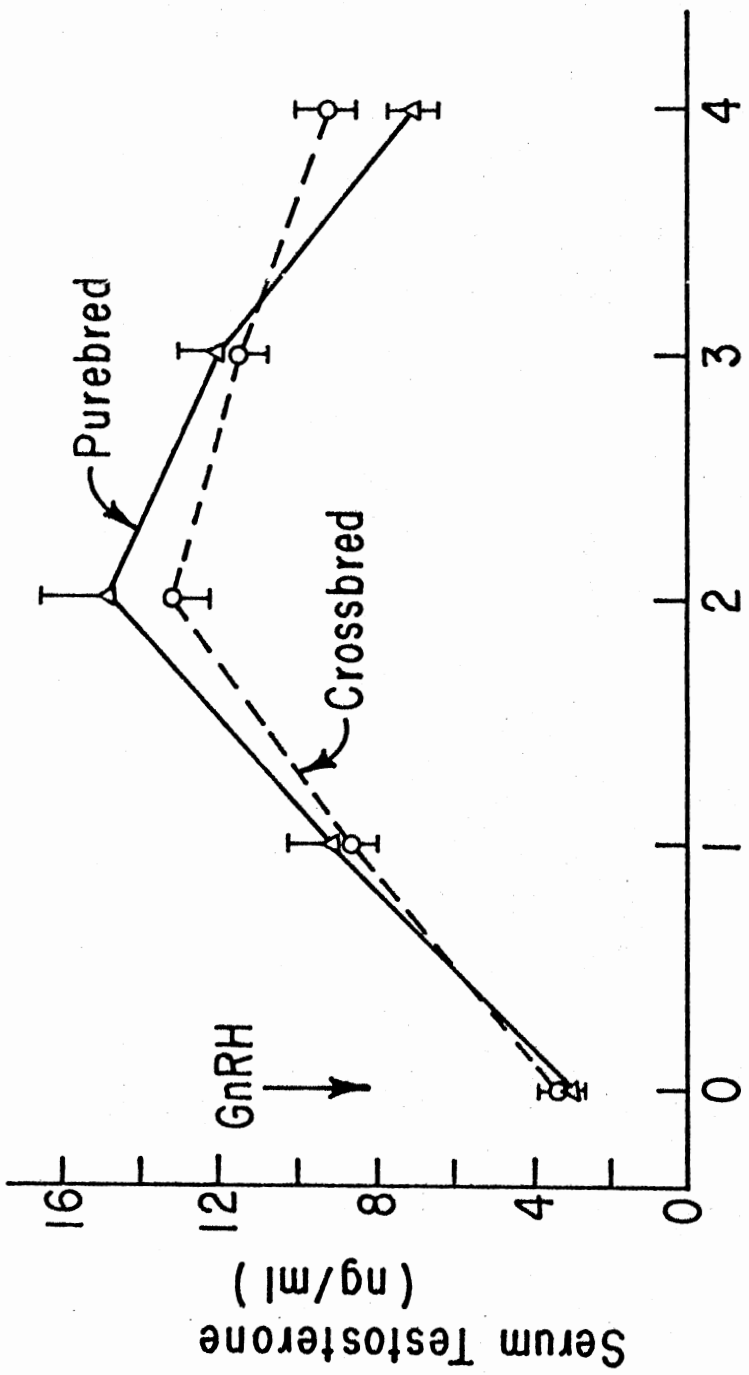

Figure 3. Serum Testosterone in Boars After GnRH

duration of testosterone secretion after stimulation and/or clearance of testosterone may be altered by breed. Sampling for more than 4 hours after GnRH treatment would be necessary to determine whether or not the observed trend for the accelerated reduction in serum testosterone concentration in purebred boars would be sustained. The greater serum testosterone for crossbred than purebred boars at four hours might be related to the greater LH concentrations for crossbred boars at three hours after GnRH treatment.

Influence of Season on Serum LH and Testosterone Response to GnRH Treatment

LH

Serum LH at 1 hour after GnRH was influenced by season ($P < .01$; Table IX) and ranged from 6.6 ± 0.4 ng/ml (Spring 1979) to 9.7 ± 0.9 ng/ml (Fall 1978). However, serum LH concentrations at 0, 2, 3 or 4 hours after GnRH treatment were not influenced by season ($P > .10$). Since the blood samples from a season were all quantified in one assay, variation between assays is confounded with seasons and might account for some of the seasonal variation observed. None of the breed X season interactions were significant ($P > .10$) for serum LH at any sampling time.

TABLE IX

INFLUENCE OF SEASON ON SERUM LH
AFTER GnRH IN BOARS

	Time After GnRH (hr)				
Season	0	1[a]	2	3	4
Spring 1977	1.8 ± 0.2[b]	7.0 ± 0.7	6.1 ± 0.7	3.5 ± 0.3	2.0 ± 0.1
Fall 1977	1.3 ± 0.2	6.7 ± 0.6	5.2 ± 0.6	2.8 ± 0.3	1.8 ± 0.2
Spring 1978	1.4 ± 0.1	8.6 ± 1.0	6.2 ± 0.6	3.2 ± 0.3	1.9 ± 0.1
Fall 1978	1.5 ± 0.1	9.7 ± 0.9	6.1 ± 0.5	3.4 ± 0.3	2.1 ± 0.2
Spring 1979	1.7 ± 0.1	6.6 ± 0.4	4.9 ± 0.3	2.8 ± 0.2	2.0 ± 0.2
$\bar{x}$	1.6 ± 0.1	7.7 ± 0.3	5.6 ± 0.2	3.2 ± 0.1	2.0 ± 0.1

[a]Significant effect of season ($P < .01$)

[b]Values in ng/ml; mean ± standard error of mean

Testosterone

Season influenced serum testosterone ($P < .01$; Table X) at the first 3 sampling times (0, 1 and 2 hr). Although season did not influence serum testosterone ($P > .10$) at 3 and 4 hours after GnRH, the breed X season interactions were significant ($P < .05$). Blood samples were assayed for testosterone at random within season, beginning with Spring 1977 samples and proceeding chronologically through the Spring 1979 samples. Therefore, between assay variation as well as variation due to time (samples were assayed over about a one year period) might account for some of the seasonal effects.

Many factors can vary from season (or rep) to season. Two of these: ambient temperature (Rhynes and Ewing, 1973; Wettemann and Desjardins, 1979; Minton, 1980) and duration of photoperiod (Minton et al., 1980) can influence gonadotropin and/or androgen synthesis both *in vitro* and *in vivo* in bulls and boars. It would be impossible to identify the causes for rep to rep variation for serum LH and testosterone response to exogenous GnRH treatment in these boars. But, it is important to note that season (or rep) differences do exist.

TABLE X

INFLUENCE OF SEASON ON SERUM TESTOSTERONE AFTER GnRH IN BOARS

Season	Time After GnRH (hr)				
	0[a]	1[b]	2[b]	3[c]	4[c]
Spring 1977	2.9 ± 0.5[d]	7.2 ± 0.8	12.2 ± 0.9	10.8 ± 1.2	8.8 ± 1.6
Fall 1977	2.5 ± 0.4	11.2 ± 2.0	19.4 ± 3.8	13.8 ± 1.7	8.1 ± 1.0
Spring 1978	1.9 ± 0.3	6.6 ± 1.0	9.9 ± 1.2	10.2 ± 1.2	7.2 ± 1.0
Fall 1978	2.9 ± 0.4	7.7 ± 0.9	12.9 ± 1.7	10.6 ± 1.2	7.6 ± 0.8
Spring 1979	4.8 ± 0.6	10.6 ± 1.0	13.6 ± 0.9	12.6 ± 1.0	10.1 ± 1.0
$\bar{x}$	3.2 ± 0.2	8.9 ± 0.5	13.8 ± 0.8	11.7 ± 0.5	8.5 ± 0.4

[a]Significant effect of season ($P < .01$)
[b]Significant effect of season ($P < .05$)
[c]Significant breed x season interaction ($P < .05$)
[d]Values in ng/ml; mean ± standard error of mean

Influence of Breed Type on LH and Testosterone Response to GnRH Treatment

Breed type significantly influenced serum LH concentrations at one ($P < .01$), two ($P < .01$) and three ($P < .05$) hours after GnRH treatment (Table XI), and serum testosterone concentrations were affected ($P < .01$) at two and four hours after treatment (Table XII). However, the breed X season interactions were significant ($P < .05$) for testosterone at 3 and 4 hours post-treatment.

LH

Serum LH concentrations were similar ($P > .10$) for all breeds before and at 4 hours after GnRH treatment (Table XI). But at 1 hour after GnRH, when maximum average LH was observed, breed type affected ($P < .01$) LH concentrations. Average serum LH (ng/ml) at 1 hour ranged from 5.8 ± 0.7 to 9.4 ± 1.1 within purebreds and from 6.2 ± 0.7 to 11.6 ± 2.1 within crossbreds. Similarly, LH concentration at 2 hours ($P < .01$) and 3 hours ($P < .05$) were influenced by breed type.

Of the 4 breeds of purebred boars in this study, Durocs responded with the greatest serum LH in terms of both magnitude and duration, Landrace boars were intermediate, and Spot and Yorkshire boars responded similarly with the lowest concentrations of LH at each sampling time.

TABLE XI

AVERAGE SERUM LH (ng/ml)
AFTER GnRH IN BOARS

Breed	n	Time After GnRH Treatment (hr)				
		0	1[a]	2[a]	3[b]	4
Duroc (D)	14	1.6 ± 0.2[c]	9.4 ± 1.1	6.8 ± 0.9	3.8 ± 0.6	2.3 ± 0.3
Landrace (L)	10	1.7 ± 0.2	7.6 ± 1.1	5.8 ± 1.2	2.9 ± 0.6	1.9 ± 0.3
Spot (S)	12	1.5 ± 0.2	6.3 ± 0.8	4.3 ± 0.6	2.4 ± 0.3	1.5 ± 0.1
Yorkshire (Y)	9	1.3 ± 0.2	5.8 ± 0.7	4.3 ± 0.6	2.4 ± 0.3	1.6 ± 0.1
All Purebreds	45	1.5 ± 0.1	7.4 ± 0.5	5.4 ± 0.4	2.9 ± 0.2	1.9 ± 0.1
D X L	19	1.8 ± 0.3	8.0 ± 0.8	5.9 ± 0.5	3.4 ± 0.4	2.1 ± 0.3
D X S	17	1.7 ± 0.2	8.4 ± 0.9	6.2 ± 0.6	3.8 ± 0.4	2.1 ± 0.2
D X Y	16	1.3 ± 0.1	6.4 ± 0.7	5.2 ± 0.5	2.9 ± 0.3	1.9 ± 0.2
L X S	13	1.7 ± 0.1	11.6 ± 2.1	8.1 ± 1.2	4.0 ± 0.5	2.2 ± 0.2
L X Y	14	1.3 ± 0.1	6.2 ± 0.7	4.4 ± 0.5	2.6 ± 0.3	1.7 ± 0.2
S X Y	15	1.5 ± 0.1	6.6 ± 0.7	5.0 ± 0.6	2.9 ± 0.3	1.8 ± 0.2
All Crossbreds	94	1.6 ± 0.1	7.8 ± 0.4	5.8 ± 0.3	3.3 ± 0.2	2.0 ± 0.1
All Boars	139	1.6 ± 0.1	7.7 ± 0.3	5.6 ± 0.2	3.2 ± 0.1	2.0 ± 0.1

[a]Significant effect of breed type ($P < .01$)

[b]Significant effect of breed type ($P < .05$)

[c]$\bar{x} \pm SE$

TABLE XII

AVERAGE SERUM TESTOSTERONE (ng/ml)
AFTER GnRH IN BOARS

Breed	n	Time After GnRH Treatment (hr) 0	1	2[a]	3[b]	4[a,b]
Duroc (D)	14	3.1 ± 0.6[b]	10.4 ± 3.5	9.3 ± 1.2	9.2 ± 1.4	6.2 ± 1.2
Landrace (L)	10	2.9 ± 0.7	7.5 ± 1.4	15.9 ± 2.5	13.4 ± 2.3	7.1 ± 1.2
Spot (S)	12	2.1 ± 0.4	6.1 ± 0.8	11.6 ± 1.4	11.2 ± 2.6	5.4 ± 1.0
Yorkshire (Y)	9	4.0 ± 1.0	12.4 ± 2.8	26.0 ± 7.6	15.2 ± 3.5	9.4 ± 2.2
All Purebreds	45	2.8 ± 0.3	9.0 ± 1.3	14.7 ± 1.9	11.9 ± 1.2	6.9 ± 0.7
D X L	19	3.2 ± 0.7	7.7 ± 1.1	11.2 ± 1.3	10.2 ± 1.0	8.8 ± 1.3
D X S	17	4.3 ± 1.0	8.0 ± 1.6	10.8 ± 1.4	9.7 ± 1.4	8.4 ± 1.5
D X Y	16	3.5 ± 0.6	11.3 ± 1.8	14.9 ± 1.5	13.8 ± 1.6	12.3 ± 2.5
L X S	13	2.2 ± 0.6	6.5 ± 1.1	11.3 ± 1.3	9.7 ± 1.3	7.1 ± 0.7
L X Y	14	2.5 ± 0.5	8.8 ± 1.4	13.2 ± 1.8	12.3 ± 1.9	7.5 ± 1.3
S X Y	15	3.7 ± 0.5	9.5 ± 0.9	18.9 ± 4.7	13.9 ± 1.7	11.0 ± 1.3
All Crossbreds	94	3.3 ± 0.3	8.8 ± 0.6	13.3 ± 1.0	11.6 ± 0.6	9.3 ± 0.7
All Boars	139	3.2 ± 0.2	8.9 ± 0.5	13.8 ± 0.8	11.7 ± 0.5	.5 ± 0.4

[a]Significant effect of breed type ($P < .01$)

[b]Significant breed x season interaction ($P < .05$)

[c]$\bar{x}$ ± SE

Of the 6 crossbred groups, the 3 involving the Yorkshire breed (DY, LY and SY) were very similar in LH response to GnRH and reached maximum concentrations of only 6.4 ± 0.7, 6.2 ± 0.7 and 6.6 ± 0.7 ng/ml, respectively. These values were less than the maximum values attained by the other 3 crossbred groups (11.6 ± 2.1 ng/ml for LS; 8.4 ± 0.9 ng/ml for DS; 8.0 ± 0.8 ng/ml for DL), and less than that of purebred Duroc (9.4 ± 1.1 ng/ml) or Landrace (7.6 ± 1.1 ng/ml). The response for LS (11.6 ± 2.1 ng/ml) was the greatest average LH concentration observed.

Breed of sire influenced ($P < .05$) serum LH only at 1 hour after GnRH (Table XVIII, Appendix), however, breed of dam was a significant source of variation ($P < .05$) for serum LH at each sampling time after treatment (Table XIX, Appendix). Boars sired by Landrace boars as well as boars out of Duroc or Spot sows attained greater average concentrations of serum LH in response to GnRH treatment.

These data indicate genetic influences on the ability of the pituitary of 7 month old boars to secrete LH in response to exogenous GnRH treatment. Thus, breed of boar should be considered when designing experiments to study pituitary function in puberal animals.

Testosterone

Breed type means for serum testosterone before GnRH treatment (Table XII) ranged from 2.1 ± 0.4 to 4.3 ± 1.0 ng/ml and were not affected by breed ($P > .10$). However,

breed type influenced ($P < .01$) serum testosterone at 2 hours after GnRH, when maximum average serum testosterone was observed for all breed groups except purebred Duroc boars. Average serum testosterone (ng/ml) at 2 hours after treatment ranged from 9.3 ± 1.2 to 26.0 ± 7.6 within purebreds and from 10.8 ± 1.4 to 18.9 ± 4.7 ng/ml within crossbreds. Similarly, breed type influenced ($P < .01$) serum testosterone concentration 4 hours after GnRH, however, the breed X season interaction was also significant ($P < .05$) at 3 and 4 hours post-treatment.

Investigation of the serum testosterone responses to GnRH for the 4 purebred groups reveals two striking phenomena: purebred Yorkshire boars had maximum testosterone concentrations which were nearly double (26.0 ± 7.6 ng/ml) the next greatest purebred maximum (15.9 ± 2.5 ng/ml for Landrace), and testosterone concentrations for purebred Durocs reached a maximum value at 1 hour after GnRH and remained relatively unchanged for the next 2 hours. This response is in contrast to the relatively linear increase in testosterone concentration until 2 hours after GnRH observed in the other breed types. The three Yorkshire crossbred groups had average maximum serum testosterone values (13.2 ± 1.8 ng/ml for LY; 14.9 ± 1.5 ng/ml for DY; and 18.9 ± 4.7 ng/ml for SY) which were greater than the means for the other 3 crosses (11.2 ± 1.3 ng/ml for DL; 11.3 ± 1.3 ng/ml for LS; and 10.8 ± 1.4 ng/ml for DS).

In contrast, DL, LS and DS had the greatest LH response to GnRH and the Yorkshire crosses had a lesser response.

The crossbred breed groups with the greatest capacity to synthesize and secrete LH in response to GnRH secreted less testosterone after treatment. At first, this relationship appears non-physiological, because LH usually has a positive influence on androgen secretion in most mammals. However, consider the hypothesis that only a threshold or minimal amount of LH is required by the testes at the cellular receptor to achieve maximum testosterone secretion, and greater quantities of LH do not influence synthesis of testosterone. Also, assuming that blood sampling was frequent enough to assess the maximum response, maybe the values obtained for LH at one hour and testosterone at two hours post-treatment reflect the true physiological state of the animal. Negative feedback of testosterone on LH exists in boars (Ford and Schanbacher, 1977), and may cause the inverse relationship between breed groups for average maximum LH and testosterone. Negative testosterone feedback may further support the "threshold" concept and enforce the conjecture that serum hormone concentrations after GnRH indicate the true "physiological state" of the animal. Injection of GnRH may be a useful tool for "ranking" groups of animals for testicular endocrine function. Because breed differences were observed for serum LH and testosterone after GnRH injection,

that were not observed before treatment, GnRH injection may be a tool for assessing breed differences for endocrine function.

Breed of dam influenced ($P < .05$) testosterone concentrations only at 1 hour post-GnRH treatment (Table XX, Appendix), however, breed of sire influenced testosterone concentrations at 2 and 3 hours ($P < .05$) and tended to influence ($P < .10$) serum testosterone at 1 and 4 hours after GnRH (Table XXI, Appendix). Boars sired by Yorkshire boars and boars out of Yorkshire sows tended to secrete the greatest quantities of testosterone in response to GnRH treatment.

These data indicate breed differences for the ability of the testes of 7 month old boars to respond to GnRH induced LH release with increased testosterone secretion. Breed type may influence testes function at maturity or only pubertal maturation may be affected. But, breed of boar should be considered when studies are conducted to assess androgen synthesis and secretion by testes.

Relationships Between Serum LH and Testosterone After GnRH

Partial correlation coefficients among serum LH concentrations at each sampling time (Table XIII) ranged from .04 ($P > .25$; between LH prior to treatment and LH at 1 hour after GnRH) to .87 ($P < .001$; between LH concentration

TABLE XIII

PARTIAL CORRELATION COEFFICIENTS AMONG SERUM LH CONCENTRATIONS IN BOARS AFTER GnRH

	LH After GnRH (hr)			
LH After GnRH (hr)	1	2	3	4
0	.04[a]	.16[a]	.31	.42
1	---	.66	.61	.44
2	---	---	.87	.68
3	---	---	---	.82

[a] $P > .05$, all other correlations are significant ($P < .05$)

at 2 hours post-GnRH and LH at 3 hours after treatment). Most correlations, however, were in the moderate range (.3 to .6) and were all positive. These results indicate that the maximum serum LH response to GnRH treatment was not related to pre-treatment LH concentration.

Partial correlation coefficients among serum testosterone concentrations at each sampling time (Table XIV) were all positive and significant ($P < .05$), ranging from .27 to .62. These data indicate a relationship among serum testosterone concentrations in blood samples taken from 7 month old boars prior to and after injection of 200 μg of GnRH.

Serum testosterone concentrations at 4 hours after GnRH was significantly correlated ($P < .01$) with serum LH at 2, 3 and 4 hours ($r = .26$, .31 and .34; Table XV). All other correlations between quantities of LH and testosterone were small and non-significant. In contrast, LH concentration in a given blood sample in non-treated animals is positively correlated with testosterone in a blood sample taken one hour later in boars ($r = .22$, Welsh and Johnson, 1978; $r = .26$, Welsh and Johnson, 1979) and bulls ($r = .34$, Welsh and Johnson, 1978; $r = .64$, Minton, 1980).

TABLE XIV

PARTIAL CORRELATION COEFFICIENTS AMONG SERUM TESTOSTERONE CONCENTRATIONS IN BOARS AFTER GnRH

	Testosterone after GnRH (hr)			
Testosterone After GnRH (hr)	1	2	3	4
0	.42[a]	.27	.39	.36
1	---	.42	.52	.33
2	---	---	.62	.43
3	---	---	---	.56

[a]All correlations are significant ($P < .05$)

TABLE XV

PARTIAL CORRELATION COEFFICIENTS
BETWEEN SERUM LH AND
TESTOSTERONE AFTER
GnRH IN BOARS

	Testosterone After GnRH (hr)				
LH After GnRH (hr)	0	1	2	3	4
0	.17	.17	-.06	-.01	.10
1	-.16	.01	.09	.08	.16
2	-.13	-.06	.02	.06	.26[a]
3	0	-.01	.06	.11	.31[a]
4	.09	0	.01	.10	.34[a]

[a] $P < .01$

Relationship Between Testicular Characteristics and Endocrine Response to GnRH

Most of the correlation coefficients between testicular characteristics and serum LH and testosterone concentrations were small and non-significant (Table XXII, Appendix). Testicular weight, in general, was negatively related to serum LH concentrations and positively related to testosterone concentrations.

CHAPTER V

SUMMARY

The objective of this experiment was to determine the influence of breed on testicular development and endocrine function of boars. Purebred and crossbred boars were evaluated at about 7 months of age.

Crossbred boars weighed 7 kg more than purebred boars at the same age. Crossbred, as compared to purebred boars, had 19% heavier testes ($P < .01$) that contained 33% more sperm cells ($P < .01$), 14% heavier capita-corpora epididymides ($P < .01$) that contained 39% more sperm cells ($P < .01$), and 15% heavier caudae epididymides ($P < .01$) with 22% more sperm cells ($P < .05$). These findings confirm those of previous studies which suggested that crossbred boars have larger testes and epididymides which contain more sperm than purebred boars at the same age. Breed of boar influenced ($P < .05$) testicular weight, capita-corpora epididymidal weight, capita-corpora epididymidal sperm number, caudae epididymidal weight and caudae epididymidal sperm number.

Testicular development may commence at a younger age and/or proceed at a more rapid rate in crossbred boars than in purebred boars. These factors could result in

larger testes at seven months of age. Studies have not been conducted to investigate the influence of crossbreeding on testicular or reproductive characteristics of boars after sexual maturity. Before recommendations can be made to producers regarding the use of crossbred boars to increase profits, characteristics of mature boars should be studied. The present study does indicate, however, that crossbred boars could probably be used to breed sows on a regular basis at a younger age than purebred boars. The results suggest that crossbred boars reach "puberty", as determined by testicular development, at a younger age than purebred boars.

Two hormones important to normal male reproduction, testosterone and LH, were quantified in blood serum samples taken from the boars after GnRH injection to determine if breed influences endocrine function. GnRH was injected to maximize hormone secretion in all boars. Serum LH concentrations for all boars ($n = 139$) increased from 1.6 ± 0.1 ng/ml before GnRH to a maximum value of 7.7 ± 0.3 ng/ml at one hour and then decreased to 2.0 ± 0.1 ng/ml at four hours after treatment. Serum testosterone concentrations increased from 3.2 ± 0.2 ng/ml before GnRH to a maximum value of 13.8 ± 0.8 ng/ml at two hours and then decreased to 8.5 ± 0.4 ng/ml by four hours after GnRH injection.

Crossbred boars had greater ($P < .05$) serum LH concentrations than purebred boars only at three hours after GnRH

(3.3 ± 0.2 vs 2.9 ± 0.2 ng/ml, respectively). And, testosterone was greater ($P < .05$) in crossbred than purebred boars only at four hours after GnRH (9.3 ± 0.7 vs 6.9 ± 0.7 ng/ml, respectively). Except for these slight differences, the endocrine response after GnRH for purebred and crossbred boars was similar.

Breed influenced ($P < .05$) serum LH at one, two and three hours after GnRH and testosterone concentrations at two and four hours after GnRH injection. These data indicate that different breeds of boars may secrete different quantities of LH and testosterone in response to GnRH injection, or clearance rate of testosterone and LH from the blood may be influenced by breed.

The differences in endocrine function and testicular weights and sperm numbers demonstrated by this experiment indicate that breed influences the hypophyseal-testicular endocrine function of boars at seven months of age. These differences may be related to variation in reproductive performance of boars of various breeds.

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APPENDIX

TABLE XVI

INFLUENCE OF BREED OF SIRE ON TESTICULAR AND EPIDIDYMIDAL CHARACTERISTICS OF BOARS

	Breed of Sire			
	Duroc	Landrace	Spot	Yorkshire
No. Boars	35	29	37	35
BW[a] (Kg)	114.8 ± 2.1[h]	112.3 ± 2.1	112.7 ± 2.3	111.1 ± 2.5
TW[b] (G)	261.9 ± 10.4	270.1 ± 12.7	283.4 ± 10.5	289.0 ± 9.9
CCEW[c] (G)[i]	31.9 ± 1.6	27.4 ± 1.2	30.4 ± 1.4	31.7 ± 1.3
CEW[d] (G)	35.7 ± 1.4	33.9 ± 1.5	33.0 ± 1.4	35.1 ± 1.3
TS[e] (X 10^9)	26.8 ± 2.3	34.5 ± 4.7	30.2 ± 2.9	33.2 ± 2.7
CCES[f] (X 10^9)	24.1 ± 2.3	25.4 ± 3.0	27.9 ± 2.8	27.5 ± 3.0
CES[g] (X 10^9)	54.1 ± 4.6	48.9 ± 5.2	51.3 ± 5.2	47.1 ± 4.0

[a]Body weight

[b]Testicular weight

[c]Capita-corpora epididymidal weight

[d]Caudae epididymidal weight

[e]Testicular sperm number

[f]Capita-corpora epididymidal sperm number

[g]Caudae epididymidal sperm number

[h]$\bar{x}$ ± SE ; [i]Significant breed of sire effect ($P < .05$)

TABLE XVII

INFLUENCE OF BREED OF DAM ON TESTICULAR AND EPIDIDYMIDAL CHARACTERISTICS OF BOARS

	Breed of Dam			
	Duroc	Landrace	Spot	Yorkshire
No. Boars	39	34	33	30
BW[a] (Kg)[i]	114.2 ± 1.8[h]	108.5 ± 2.0	115.0 ± 2.7	113.1 ± 2.7
TW[b] (G)	272.3 ± 12.1	288.3 ± 8.9	265.7 ± 11.4	280.3 ± 9.9
CCEW[c] (G)	30.6 ± 1.6	30.7 ± 1.4	29.5 ± 1.3	31.1 ± 1.3
CEW[d] (G)[i]	37.0 ± 1.4	34.5 ± 1.4	31.7 ± 1.5	34.0 ± 1.2
TS[e] (X 10^9)	33.1 ± 3.8	28.8 ± 2.8	30.2 ± 2.7	31.9 ± 2.8
CCES[f] (X 10^9)	25.6 ± 2.5	26.3 ± 2.8	27.6 ± 3.3	25.7 ± 2.4
CES[g] (X 10^9)	53.0 ± 4.8	51.1 ± 4.9	46.1 ± 4.2	51.2 ± 5.1

[a]Body weight

[b]Testicular weight

[c]Capita-corpora epididymidal weight

[d]Caudae epididymidal weight

[e]Testicular sperm number

[f]Capita-corpora epididymidal sperm number

[g]Caudae epididymidal sperm number

[h]$\bar{X}$ ± SE

[i]Significant breed of dam effect ($P < .05$)

TABLE XVIII

INFLUENCE OF BREED OF SIRE ON SERUM LH RESPONSE TO GnRH IN BOARS

	Breed of Sire			
LH After GnRH (hr)	Duroc	Landrace	Spot	Yorkshire
0	1.6 ± 0.2[a]	1.7 ± 0.1	1.5 ± 0.1	1.4 ± 0.1
1[b]	7.8 ± 0.6	9.6 ± 1.0	6.9 ± 0.5	6.6 ± 0.4
2	5.6 ± 0.4	6.6 ± 0.6	5.4 ± 0.5	5.1 ± 0.3
3	3.3 ± 0.3	3.7 ± 0.3	3.0 ± 0.2	2.8 ± 0.2
4	2.0 ± 0.2	2.1 ± 0.2	1.8 ± 0.1	1.9 ± 0.1

[a] $\bar{x}$ ± SE; ng/ml

[b] Significant effect of breed of sire ($P < .05$)

TABLE XIX

INFLUENCE OF BREED OF DAM ON SERUM LH RESPONSE TO GnRH IN BOARS

	Breed of Dam			
LH After GnRH (hr)	Duroc	Landrace	Spot	Yorkshire
0	1.6 ± 0.1[a]	1.6 ± 0.2	1.6 ± 0.1	1.3 ± 0.1
1[b]	8.6 ± 0.5	7.0 ± 0.6	9.0 ± 1.0	5.8 ± 0.4
2[b]	6.6 ± 0.4	5.4 ± 0.5	6.0 ± 0.6	4.3 ± 0.4
3[b]	3.8 ± 0.2	2.8 ± 0.2	3.4 ± 0.3	2.5 ± 0.2
4[b]	2.3 ± 0.2	1.8 ± 0.2	1.9 ± 0.1	1.6 ± 0.1

[a] $\bar{x}$ ± SE; ng/ml

[b] Significant effect of breed of dam ($P < .05$)

TABLE XX

INFLUENCE OF BREED OF DAM ON SERUM TESTOSTERONE RESPONSE TO GnRH IN BOARS

Testosterone After GnRH (hr)	Breed of Dam			
	Duroc	Landrace	Spot	Yorkshire
0	4.1 ± 0.6[a]	2.7 ± 0.4	2.5 ± 0.3	3.2 ± 0.4
1[b]	11.1 ± 1.5	7.7 ± 0.8	6.4 ± 0.6	9.9 ± 0.4
2	12.2 ± 1.0	13.2 ± 1.0	12.5 ± 2.4	17.8 ± 2.6
3	11.5 ± 1.0	11.7 ± 0.9	10.0 ± 1.2	13.7 ± 1.6
4	10.0 ± 1.2	7.4 ± 0.7	7.3 ± 0.9	9.2 ± 1.1

[a] $\bar{x}$ ± SE; ng/ml

[b] Significant effect of breed of dam ($P < .05$)

TABLE XXI

INFLUENCE OF BREED OF SIRE ON SERUM TESTOSTERONE RESPONSE TO GnRH IN BOARS

Testosterone After GnRH (hr)	Breed of Sire			
	Duroc	Landrace	Spot	Yorkshire
0	2.8 ± 0.3[a]	2.8 ± 0.5	3.4 ± 0.5	3.7 ± 0.5
1[b]	8.1 ± 1.4	7.5 ± 0.9	8.6 ± 0.8	11.3 ± 1.2
2[c]	10.1 ± 0.7	12.7 ± 1.3	13.4 ± 1.0	19.4 ± 3.0
3[c]	9.4 ± 0.8	11.2 ± 1.2	12.2 ± 1.2	14.1 ± 1.2
4[b]	7.1 ± 0.9	8.1 ± 0.9	8.1 ± 0.8	11.0 ± 1.4

[a] $\bar{x}$ ± SE; ng/ml

[b] Effect of breed of sire approached significance ($P < .10$)

[c] Significant effect of breed of sire ($P < .05$)

TABLE XXII

PARTIAL CORRELATION COEFFICIENTS BETWEEN TESTICULAR CHARACTERISTICS AND ENDOCRINE RESPONSE TO GnRH IN BOARS

LH After GnRH (hr)	BW[a]	TW[b]	CCEW[c]	CEW[d]	TS[e]	CCES[f]	CES[g]
0	.21	-.01	-.05	.03	-.20	-.18	-.12
1	.01	-.27[h]	-.23[h]	-.04	-.10	-.14	-.11
2	.03	-.15	-.19	-.04	-.02	-.15	-.09
3	.09	-.12	-.21	-.06	-.01	-.22[h]	-.12
4	.06	-.08	-.18	-.02	0	-.23[h]	-.10
Testosterone After GnRH (hr)							
0	-.11	.29[h]	.07	.06	.12	-.10	-.03
1	-.07	.08	0	.17	.12	-.03	.14
2	-.01	.06	0	.12	-.02	-.10[h]	.17
3	.09	.10	.01	.13	-.07	-.25[h]	.16
4	.01	-.02	-.07	-.12	-.08	-.27[h]	-.03

[a]Body weight

[b]Testicular weight

[c]Capita-corpora epididymidal weight

[d]Caudae epididymidal weight

[e]Testicular sperm number

[f]Capita-corpora epididymidal sperm number

[g]Caudae epididymidal sperm number

[h]$P < .05$

TABLE XXIII

DISTRIBUTION OF BOARS WHICH WERE CASTRATED

Breed	Season			
	Spring 77	Fall 77	Fall 78	Spring 79
Duroc (D)	3	3	4	3
Landrace (L)	3	3	1	2
Spot (S)	4	3	3	2
Yorkshire (Y)	3	3	4	0
DL	3	4	3	7
DS	4	4	3	5
DY	3	4	3	5
LS	4	4	4	2
LY	4	3	4	3
SY	4	4	3	5
Total	35	35	32	34

TABLE XXIV

DISTRIBUTION OF BOARS WHICH WERE BLED

	Season				
Breed[a]	Spring 77	Fall 77	Spring 78	Fall 78	Spring 79
DD	3	3	1	4	3
LL	2	3	1	2	2
SS	3	2	2	3	2
YY	3	2	0	4	0
DL	2	3	4	3	7
DS	4	3	2	3	5
DY	2	4	2	3	5
LS	3	2	2	4	2
LY	3	2	2	4	3
SY	3	3	1	3	5
Total	28	27	17	33	34

[a]D = Duroc; L = Landrace; S = Spot; Y = Yorkshire

TABLE XXV

DISTRIBUTION OF BOARS BY SIRE

	Season Farrowed					
Duroc Sires	Fall 76	Spring 77	Fall 77	Spring 78	Fall 78	Total Pigs
1	2	4	•	•	•	6
2	4	2	•	•	•	6
3	1	•	•	•	•	1
4	•	3	•	•	•	3
5	•	•	3	1	•	4
6	•	•	1	4	3	8
7	•	•	•	3	•	3
8	•	•	•	2	3	5
9	•	•	•	•	4	4
Landrace Sires						
1	2	•	•	•	•	2
2	3	1	•	3	•	7
3	3	2	•	•	•	5
4	1	4	3	2	•	10
5	•	2	2	•	•	4
6	•	•	•	1	1	2
7	•	•	•	1	3	4
8	•	•	•	•	2	2
Spot Sires						
1	2	•	•	•	•	2
2	3	2	•	1	•	6
3	3	•	•	•	•	3
4	2	•	•	•	•	2
5	•	4	•	•	•	4
6	•	2	4	2	2	10
7	•	•	1	•	•	1
8	•	•	•	2	3	5
9	•	•	•	2	3	5
10	•	•	•	•	3	3

TABLE XXV (Continued)

Yorkshire Sires	Season Farrowed					Total Pigs
	Fall 76	Spring 77	Fall 77	Spring 78	Fall 78	
1	4	2	2	1	.	9
2	3	1	.	.	.	4
3	2	.	.	.	.	2
4	.	2	1	.	.	3
5	.	4	.	.	.	4
6	.	.	.	6	.	6
7	.	.	.	1	.	1
8	.	.	.	1	1	2
9	.	.	.	.	2	2
10	.	.	.	.	2	2

VITA

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