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Allan Schinckel
University of Nebraska-Lincoln

R. K. Johnson
University of Nebraska-Lincoln, rjohnson5@unl.edu

R. A. Pumfrey
University of Nebraska-Lincoln

Dwane R. Zimmerman
University of Nebraska-Lincoln

TESTICULAR GROWTH IN BOARS OF DIFFERENT GENETIC LINES AND ITS RELATIONSHIP TO REPRODUCTIVE PERFORMANCE[1]

Allan Schinckel[2], R. K. Johnson[3], R. A. Pumfrey[4] and Dwane R. Zimmerman[3]

University of Nebraska, Lincoln 68583

Summary

Testicular growth of 377 boars was compared by obtaining in situ measurements of testes width and length and excised tissue weights. Two experiments involved a line selected nine generations for ovulation rate (OR) and a control line (CL), and two experiments contained boars of the OR line and two other lines; WL, a Large White-Landrace cross, and a line founded by crossing lines OR and CL and selected six generations for increased average daily gain and decreased backfat (LG line). In situ testes measurements were similar for the OR and CL lines and were curvilinearly related to age. The LG line had smaller in situ measurements than the OR line (P<.05) when both unadjusted means and means adjusted for body weight were compared. The OR line had 10.5% heavier testes than the CL line at 90.8 kg and a 9 to 15% advantage at 120, 141, 162 and 183 d of age. The OR line had more rapid testicular development from 120 to 183 d of age (P<.05) than the CL line. The LG line had significantly lower excised testes weights (17 to 50% less), a lower percentage of tubules that showed active spermatogenesis and lower mean diameter of the seminiferous tubules (P<.05) than the OR line. The relative differences between lines OR, CL and LG suggest that selection for lean growth rate has resulted in less rapid testicular development and increased age at puberty. The correlations of testes weights and in situ testes measurements taken at the time of castration were between .76 and .93. The correlations of testes width and testes length with epididymides weights were slightly lower, and correlations of body weight and testes weight ranged from .51 to .70. Mean diameter of the seminiferous tubules and percentage of tubules with active spermatogenesis were correlated with measurements of testes size (r = .50 to .61) and body weight at the time of castration (r = .29 to .36). Correlations of excised testes weights with number born in the boar's contemporary litter and ovulation rate of full sibs were uniformily positive. The correlations of measurements of testes size and backfat (r = −.09 to .20) suggest that the phenotypic relationship between testes growth and body composition is small. However, the response found in the LG line suggests a negative genetic relationship between lean growth rate and testicular growth rate.

(Key Words: Boars, Testicular Growth, Ovulation Rate, Lean Growth, Reproduction.)

Introduction

Improved reproductive efficiency will increase the overall efficiency of swine production. Response to selection could be improved if some characteristic of the boar could be used as a predictor of the reproductive efficiency of genetically related females. The same gonadotropic hormones stimulate the gonads of both sexes, and a positive relationship between testis size and ovulation rate has been found in mice (Land, 1973; Islam et al., 1976; Joakimsen and Baker, 1977) and sheep (Carr and Land, 1973).

Testicular growth may be an indicator of the reproductive performance of boars. Lines or crosses that have larger testes at a constant age generally have greater sperm numbers and superior mating efficiency (Hauser et al., 1952; Wilson et al., 1977; Neely et al., 1979).

Selection for lean growth rate may delay sexual maturation. Andresen (1976) found significantly higher levels of 5α-androstenone and testosterone in the systemic plasma of

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[2] Present address: Anim. Sci. Dept., Purdue Univ., West Lafayette, IN 47907.

[3] Anim. Sci. Dept., Univ. of Nebraska.

[4] Present address: Fairbault, MN 55021.

boars selected for fatness and a low rate of gain than in boars selected for low backfat thickness and a high rate of gain. Gray et al. (1971) found that the testosterone level in the spermatic vein blood of boars with the highest backfat was significantly higher than the testosterone level of boars with the lowest backfat. Allrich et al. (1981) found that selection for efficiency of lean growth in rats decreased testes weight at 85 d of age. Also, increased age and weight at vaginal opening were found in lines selected for both rate and efficiency of lean growth.

This paper presents the results of four experiments that were conducted to evaluate 1) differences in rates of tesicular growth among lines that differed in ovulation and growth rate and 2) relationship of testes growth with body weight, age and reproductive characteristics of female relatives.

Materials and Methods

Data were collected during four experiments from 377 boars. Experiments 1 and 2 involved the Gene Pool line selected for increased ovulation rate (OR) and the control line (CL; Zimmerman and Cunningham, 1975). No significant correlated responses in growth traits (Newton et al., 1977) or carcass traits (England et al., 1977; Cunningham et al., 1979) have been found in the OR line.

The first experiment involved the measurement of 103 (48 CL and 55 OR) boars of the first generation of relaxed selection following nine generations of selection for ovulation rate. Boars were randomly assigned to be castrated at 225 d of age or 90.8 kg (table 1). They were fed ad libitum from about 60 d of age to about 90.8 kg; interval feeding (4 h/d) was used thereafter.

In situ measurements of testes width (TWH) and testis length (TL) were started at 84 d of age when the boars weighed approximately 31 kg. Measurements were made with the use of calipers and were taken at approximately 3-wk intervals up until the time of castration. Boars were snared and measured while standing squarely on a level floor. Three to six measurements were made on boars that were castrated at 90.8 kg. Seven measurements were made on boars castrated at 225 d of age. The TWH was the width of both testes, and TL was the length

TABLE 1. NUMBER OF BOARS IN EACH EXPERIMENT

Time of castration	Line[a] OR	CL	LG	WL
	Experiment 1			
90.8 kg	24	28		
225 d	24	27		
	Experiment 2			
120 d	11	12		
141 d	10	12		
162 d	12	11		
183 d	10	11		
	Experiment 3			
140 d	10			15
160 d	10			13
Measured to 160 d but not castrated			19	28
	Experiment 4			
120 d	8		9	11
140 d	10		7	13
160 d	9		9	14

[a]OR = ovulation rate select, CL = ovulation rate control, LG = index select for average daily gain and backfat, WL = cross among Large White and Landrace.

of the testis from the top of the epididymis to the bottom of the testis.

Boars were anesthetized with sodium thiamylal and castrated. The tissues were wrapped in plastic bags and placed on ice until weights were determined (4 to 6 h). Total testis (testis + epididymis, TTW), testis (without epididymis, TW) and epididymis weights (EW) were taken. The weights of both sides were added for analyses.

In Exp. 2, 89 (46 CL and 43 OR) boars of the second generation of relaxed selection were randomly assigned to be castrated at either 120, 141, 162 or 183 d of age (table 1). Boars were fed ad libitum. Measurements of testes width, testis length and body weight were taken at each age until castration.

The third experiment included 95 boars of lines LG, OR and WL. The OR boars were a sample from the second generation of relaxed selection. The LG line was formed from a cross of third generation OR and CL line pigs (Cleveland et al., 1982) and was mass selected for six generations on the index: I = 100 + 286.6 (average daily gain, kg)−100 (backfat, cm). Total response after five generations was .08 kg average daily gain, −.18 cm backfat and 29 index units (Cleveland et al., 1982). The WL boars were the F_1 offspring of reciprocally crossed Landrace and Large White and were included to improve the precision of within line estimates of correlation coefficients.

One-half of the WL boars and all of the LG boars were needed for breeding, and only intact testes measurements were taken. The remaining WL and OR boars were castrated at 140 or 160 d of age. The boars were fed ad libitum, and body weight and in situ measurements of testicular growth were taken at 120, 140 and 160 d of age.

The fourth experiment included 90 boars of lines LG, OR and WL. Boars were randomly assigned to be castrated at either 120, 140 or 160 d of age. The LG and OR boars were of the second and third generations of relaxed selection, respectively, and the WL boars were of the F_2 generation. Boars were fed ad libitum, and in situ measurements of testicular growth were taken at 100, 120, 140 and 160 d of age.

Histological measurements were made in Exp. 4. Immediately after the testes were weighed, two wedges of tissue were taken from the left testis of each boar. The tissue samples were fixed for 24 h in Bouins fluid and then transfered to 70% ethanol. Fixed tissues were embedded in paraffin wax, and 5 to 7-μm sections were stained with hematoxylin-eosin. The mean seminiferous tubule diameter was calculated from the measurement of 40 round tubules (20 tubules/original tissue sample). The percentage of tubules having a lumen and showing active spermatogenesis were estimated from the evaluation of 100 tubules (50 tubules/ tissue sample).

Statistical analysis of data was made by general linear model procedures (SAS, 1979). The models used to analyze the data are presented in table 2. In situ measurements and body weights, which were taken at several ages on each boar were fitted to model 1. In addition, the data were analyzed according to model 1 with age considered a continuous variable. The effects of age, age^2, age × line and age^2 × line were examined. The boar within

TABLE 2. MODELS USED FOR ANALYSES

Model no.	Experiment	Model[a]	Traits[b]
1	1,2,3,4	$Y_{ijk} = \mu + L_i + B_j/L_i + A_k + A{*}L_{ik} + e_{ijk}$	BW, TL, TWH
2	3,4	$Y_{ijk} = \mu + L_i + B_j/L_i + A_k + A{*}L_{ik} + bBW_{ijk} + e_{ijk}$	TWH, TL
3	1,2,3,4	$Y_{ijk} = \mu + L_i + A_k + A{*}L_{ik} + e_{ijk}$	TTW, TW, EW
4	2,3,4	$Y_{ijk} = \mu + L_i + A_k + L{*}A_{ik} + bBW_{ijk} + e_{ijk}$	TTW, TW, EW

[a]Definition of terms: μ = overall mean; L_i = fixed effect of i^{th} line; B_j/L_i = random effect of j^{th} boar of the i^{th} line; A_k = fixed effect of the k^{th} constant age; $A{*}L_{ik}$ = interaction of the i^{th} line and k^{th} age; b = partial regression of Y on the independent variable, pooled across lines and ages; BW_{ijk} = body weight of the j^{th} boar of the i^{th} line at the k^{th} age; Y = observation; e_{ij}, e_{ijk} = residual.

[b]BW = body weight, TL = in situ testes length, TWH = in situ testes width, TW = testes weight, EW = epididymides weight and TTW = testes + epididymides weight.

line mean square was used for testing line effects, and the residual mean square was used for testing age and interaction effects.

The data from Exp. 3 and 4 were fitted to model 2 to estimate the partial regression of testes measurements on body weight, pooled across lines and ages. Preliminary analyses failed to reveal a significant interaction between either age or line and the regression of testes measurements on body weight.

Excised testes weights from all experiments, and the histological traits from Exp. 4, were fitted to model 3. Model 4 was used to estimate the regression coefficient for excised testes weights on body weight for data from Exp. 2, 3 and 4. The regressions of testes weights on body weight were pooled across lines and ages because the interactions of the regression on body weight were not significant.

The usefulness of in situ measurements to predict actual testes and epididymides weight was evaluated by estimating the pooled within line correlations of testes width and length at the time of castration with the excised tissue weights. In Exp. 2, 3 and 4, the correlations were not significantly different at the various ages and were pooled across lines and ages.

Experiment 4 data were used to calculate within line correlations of histological measurements with measurements of testes size and body weight.

Correlation coefficients of female reproductive traits with testicular measurements and histological traits of the boars were calculated to evaluate the usefulness of testicular characteristics as predictors of female reproduction. Female reproductive traits included ovulation rate (ORFS) and age at puberty (APFS) of full sibs. Also included were available data for dam's age at puberty (DAMPUB), dam's ovulation rate (DAMOR), the size of litter in which a boar was born (NBORN) and weaned (NWEAN) and the number born in the dam's previous litter (NBORNI). Correlations were calculated within line and castration age and pooled. For APFS and ORFS, the record for each boar was

TABLE 3. LEAST-SQUARES MEANS FOR OVULATION RATE SELECT (OR) AND CONTROL LINES (CL) FOR IN SITU TESTES MEASUREMENTS

Line	Measurement age, d	No.	Testes width (cm) $\bar{X}$	Testes width (cm) SE	Testis length (cm) $\bar{X}$	Testis length (cm) SE
			Experiment 1			
OR	84	48	5.81	.11	6.32	.12
	112	48	8.19	.11	8.70	.12
	132	48	10.08	.11	10.68	.12
	153	43	11.43	.12	12.31	.14
	173	29	12.59	.15	13.22	.17
	198	25	13.29	.16	14.08	.19
	225	24	13.86	.17	15.08	.20
CL	84	55	5.77	.11	6.24	.13
	112	55	8.28	.11	8.82	.13
	132	54	10.00	.11	10.61	.13
	153	47	11.24	.12	12.41	.14
	173	42	12.74	.15	13.63	.18
	198	28	13.21	.17	14.25	.20
	225	27	13.68	.17	14.96	.20
			Experiment 2			
OR	120	43	8.30	.10	9.05	.11
	141	32	9.72	.13	10.60	.15
	162	22	10.80	.16	11.54	.18
	183	10	11.65	.24	12.66	.27
CL	120	46	8.22	.10	8.90	.11
	141	34	9.37	.13	10.55	.14
	162	22	10.32	.17	11.57	.19
	183	11	11.13	.23	12.29	.26

TABLE 4. OVULATION RATE SELECT (OR) AND CONTROL (CL) LINE LEAST-SQUARES MEANS FOR EXCISED TESTES AND EPIDIDYMIDES WEIGHTS[a]

Time of castration	Testes weight (g)				Epididymides weight (g)			
	OR	SE	CL	SE	OR	SE	CL	SE
			Experiment 1					
90.8 kg	341.1	20.1	308.7	21.8	60.8	2.2	60.8	2.4
225 d	555.0	25.7	543.5	26.7	130.4	4.9	134.9	5.1
			Experiment 2[b]					
120 d	113.6	12.8	105.3	12.3	32.3	1.6	33.3	1.6
141 d	249.8	21.4	215.9	18.8	56.8	3.5	49.3	3.1
162 d	385.1	20.2	353.2	22.1	71.7	4.0	70.9	4.4
183 d	465.3	28.4	405.3	27.0	93.6	5.4	88.2	5.1

[a]Adjusted for body weight.

[b]Age linear and line X age linear (P<.05) effects for testes weight.

TABLE 5. LEAST-SQUARES MEANS FOR OVULATION RATE SELECT (OR), LEAN GROWTH SELECT (LG) AND WHITELINE (WL) FOR IN SITU TESTES MEASUREMENTS AND BODY WEIGHT IN EXPERIMENT 3

Line	Measurement age, d	Testes width (cm)		Testis length (cm)		Body weight, kg
		$\bar{X}$	SE	$\bar{X}$	SE	
		Unadjusted for body weight[a]				
OR	120	8.33	.24	8.57	.28	52.7
	140	9.52	.27	10.07	.35	70.2
	160	11.76	.25	12.57	.33	96.8
LG	120	7.88	.22	8.21	.25	62.6
	140	9.45	.13	9.93	.28	82.2
	160	10.87	.23	11.65	.25	99.9
WL	120	8.69	.15	9.39	.16	53.9
	140	10.40	.13	11.28	.16	75.5
	160	11.47	.13	12.73	.13	74.5
		Adjusted for body weight[b]				
OR	120	8.54	.18	8.74	.22	
	140	9.98	.18	10.48	.24	
	160	11.71	.25	12.54	.28	
LG	120	7.27	.19	7.69	.24	
	140	9.01	.19	9.45	.25	
	160	10.66	.18	11.49	.21	
WL	120	8.83	.11	9.50	.13	
	140	10.42	.11	11.30	.14	
	160	15.58	.12	12.81	.14	

[a]Effects (P<.05) include line, age linear and line X age quadratic interaction for testes width and testis length.

[b]Effects (P<.05) include line, age linear and line X age linear.

paired with the sib mean. The total number of boar-relative records that were available from each experiment were: Exp. 1 (ORFS, 47-150; APFS, 44-97; NBORN, 102 pairs; NBORNI, 99 pairs); Exp. 2 (ORFS, 64-91; APFS, 78-156; DAMPUB, 86 pairs; NBORN, 89 pairs; NWEAN, 89 pairs); Exp. 3 (DAMPUB, 18 pairs; DAMOR, 35 pairs; NBORN, 48 pairs) and Exp. 4 (APFS, 71-157; NBORN, 71 pairs).

Correlations of testes measurements with backfat probe also were calculated. The boars in the first experiment were probed at 90.8 kg and probe backfat was measured at 140 d of age in Exp. 2, 3 and 4 and adjusted using body weight as a covariable.

Results

Exp. 1 and 2. The least-squares means for testes width and testis length are given in table 3. Results from Exp. 1 indicate that the in situ measurements increased most rapidly between the ages of 84 and 132 d. The lines were not significantly different at any age; but in Exp. 2, the ovulation rate line tended to have larger means.

Least-squares means for excised testes weight are presented in table 4. Line differences were not significant in Exp. 1, but the ovulation rate line had 10.5% heavier testes at 90.8 kg. In Exp. 2, testes weight increased linearly with age, but the rate of change was significantly different for the OR and CL lines. Testes weight for the OR line was from 9 to 15% heavier, depending on when measured.

Exp. 3 and 4. In situ testes measurements means for Exp. 3 and 4 are presented in tables 5 and 6, respectively. Means were compared be-

TABLE 6. LEAST-SQUARES MEANS FOR OVULATION RATE SELECT (OR), LEAN GROWTH SELECT (LG) AND WHITELINE (WL) FOR IN SITU TESTES MEASUREMENTS AND BODY WEIGHT IN EXPERIMENT 4

Line	Measurement age, d	Testes width (cm) $\bar{X}$	Testes width (cm) SE	Testis length (cm) $\bar{X}$	Testis length (cm) SE	Body weight, kg
		Unadjusted for body weight[a]				
OR	100	6.38	.09	7.30	.10	37.4
	120	7.95	.11	8.85	.14	51.2
	140	10.06	.18	10.54	.19	67.3
	160	11.78	.18	12.70	.20	82.8
LG	100	6.10	.10	6.85	.11	37.9
	120	7.60	.13	8.13	.13	54.3
	140	8.87	.18	9.49	.19	74.6
	160	10.91	.26	11.45	.28	90.5
WL	100	6.43	.08	7.10	.09	33.2
	120	8.15	.08	8.72	.09	47.3
	140	9.98	.10	10.51	.11	65.3
	160	11.56	.15	12.23	.16	82.3
		Adjusted for body weight[a]				
OR	100	6.24	.08	7.15	.09	
	120	7.90	.11	8.79	.12	
	140	10.01	.16	10.53	.16	
	160	11.82	.25	12.67	.28	
LG	100	5.92	.08	6.67	.10	
	120	7.34	.12	7.81	.12	
	140	8.63	.16	9.28	.18	
	160	10.71	.23	11.26	.26	
WL	100	6.64	.07	7.33	.08	
	120	8.34	.10	8.96	.10	
	140	10.27	.13	10.81	.14	
	160	11.83	.20	12.58	.23	

[a]Effects ($P<.05$) include line, age linear, age quadratic and line × age linear for both testes width and testis length.

fore and after adjusting for body weight, which was quite different between lines. There were significant differences between the lines for rate and shape of the testicular growth curve. The LG line had heavier body weights at all ages than the OR and CL lines, but they had smaller testes measurements. In Exp. 3, boars of the LG line were 10 to 12 kg heavier than OR line boars, but they had smaller in situ testes measurements at 120 and 140 d of age. When the means were adjusted for body weight, the line differences became larger and the LG line had smaller in situ measurements at all ages in both experiments. Generally, the WL and OR lines had similar testes measurements.

The LG line had significantly lighter weight testes at 120 and 160 d of age than did the other lines (table 7). Averaged over experiments, testes and epididymides weights were similar for the OR and WL boars.

Histological data obtained from Exp. 4 are presented in table 8. At each age, LG boars had significantly fewer seminiferous tubules with active spermatogenesis and smaller tubule diameter. The differences were particularly large at 120 d of age. The percentage of the tubules with a lumen was considerably lower for the LG line at 120 d of age, but the lines were similar thereafter. The differences between the WL and OR lines were small.

Within Line Correlations. Correlations between excised testes weights and in situ testes measurements are shown in table 9. Correlations of in situ testes width and length with excised testes weight ranged from .76 to .93. Correlations of epididymides weight and in situ measurements were lower than the correlations involving testes weight. The correlation between castration age and testes weight of the boars castrated at 90.8 kg was .42, compared with correlations of .51 to .70 between body weight at castration and testes weight.

The correlations of testes weights and in situ measurements with seminiferous tubule diameter, percentage of tubules with active spermatogenesis and percentage with a lumen are presented in table 10. Approximately 25% of the variation observed in the histological traits was explained by the measurements of testes size. Correlations of histological traits with body weight were between .29 and .36. For boars of the same age, there is considerable variation in histological measurements that is independent of body weight.

Correlations of testes traits with reproductive

TABLE 7. OVULATION RATE SELECT (OR), LEAN GROWTH SELECT (LG) AND WHITELINE (WL) LEAST-SQUARES MEANS FOR EXCISED TESTES AND EPIDIDYMIDES WEIGHT[a]

Age at castration, d	Testes weight (g)						Epididymides weight (g)					
	OR	SE	LG[b]	SE	WL	SE	OR	SE	LG[b]	SE	WL	SE
					Experiment 3[c]							
140	185.8	20.3	134.6	28.0	267.3	16.5	38.9	3.7	33.7	3.6	54.4	3.0
160	372.1	26.6	310.1	29.1	406.9	23.3	72.5	4.9	67.2	3.7	81.2	4.3
					Experiment 4[c]							
120	137.7	13.4	69.9	12.3	106.9	11.4	33.1	2.0	25.9	1.8	26.6	1.7
140	229.5	19.9	181.1	28.1	257.1	17.4	47.1	2.6	36.0	3.7	53.4	2.3
160	410.2	24.9	303.7	23.0	412.9	20.1	78.3	4.1	57.9	3.8	86.4	3.3

[a]Adjusted for body weight.

[b]For line LG, testes and epididymides weight were predicted by the equation $Y = b_0 + b_1$ testes width + b_2 testis length. For testes weight, b_1 and b_2 were 32.8 ± 10.8 and 39.9 ± 9.1, respectively; for epididymides weight, b_1 and b_2 were 4.0 ± 2.7 and 6.7 ± 2.3, respectively.

[c]Effects ($P<.05$) include line, age and line X age.

traits of female relatives are presented in table 11. Correlations of excised testes weights with ovulation rate of full sibs and the size of litter in which a boar was born are uniformily positive. The majority of the correlations between measures of testes size with age at puberty of full sibs and dam are negative. In Exp. 1, testes weight was positively correlated to backfat probe (P<.05); however, in the other experiments, these correlations were small and nonsignificant.

Discussion

In Exp. 2 and 4, testes weight more than tripled from 120 to 160 d of age. This rate of growth is similar to that found by McFee and Eblen (1967), but is less rapid than the 400 to 500% increase in testes weight found over the same age period by Hauser et al. (1952). Relatively, the rate of growth of excised testes weight was greater than for the in situ measurements. This was most likely due to the fact that weight estimates volume (length times width times depth) while width and length are linear measurements.

The data suggest that selection for ovulation rate has resulted in a 10 to 12% increase in testes weights at 140 to 160 d of age. Land (1973), Islam et al. (1976) and Joakimsen and Baker (1977) also have found correlated responses between testes size and ovulation rate in mice.

Boars selected for rate of lean growth were from 14 to 20 d older than the OR and WL line boars upon reaching the same degree of testicular development. Selection for ovulation rate has increased testes size over the CL line, but the majority of the differences between the LG and OR lines appears to have been caused by a negative genetic relationship between the index and testes weight. Perhaps the effect of selection for lean growth has been to delay maturity, both compositionally and sexually. Allrich et al. (1981) found a decrease in testes weights in a line of rats selected for lean efficiency; a line in which body composition and daily gain changed in the same direction as has been found for the LG line (Wang et al., 1980; Cleveland et al., 1982).

Selection did not have a detrimental effect on female reproductive performance of the LG line. Williams (1981) evaluated the LG line via a diallel mating design and failed to find any significant line of sire effects for age at first estrus, ovulation rate or number of normal embryos. Cleveland (1981) did not detect any significant correlated response in the LG line for number born or number weaned.

Some care must be exercised when interpreting the correlations between growth rate and testis size. Average daily gain is a function of both weight and age. The relationship between growth rate and testes weight depends upon which variable, age or weight, is held constant.

TABLE 8. LEAST-SQUARES MEANS FOR HISTOLOGICAL TRAITS FOR OVULATION RATE SELECT (OR), LEAN GROWTH (LG) AND WHITELINE (WL) BOARS (EXP. 4)

		WL		OR		LG	
Trait[a]	Age, d	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
SPERM, %[b]	120	21.2	8.8	44.1	9.3	.4	8.8
	140	74.9	7.3	79.4	8.8	48.0	11.8
	160	91.4	7.1	90.5	7.3	77.4	8.4
LUMEN, %[c]	120	43.9	7.0	66.5	7.5	9.4	7.0
	140	82.1	5.9	85.3	8.8	82.2	9.4
	160	90.6	5.6	93.1	7.5	83.7	6.7
TUBDIA, μm[b]	120	90.2	8.4	113.0	8.8	68.3	8.4
	140	137.2	7.3	134.1	8.4	116.0	11.2
	160	157.4	6.7	160.2	8.9	136.1	7.9

[a]SPERM = percentage of seminiferous tubules with active spermatogenesis; LUMEN = percentage of seminiferous tubules with a lumen; TUBDIA = seminiferous tubule diameter.

[b]Effects (P<.05) include line and age.

[c]Effects (P<.05) include line, age and line X age.

TABLE 9. CORRELATIONS OF TESTES WIDTH (TWH), TESTIS LENGTH (TL) AND AGE OR BODY WEIGHT AT THE TIME OF CASTRATION WITH TESTES (TW), EPIDIDYMIDES (EW) AND TOTAL TESTES WEIGHTS (TTW)[a]

Trait	TW	EW	TTW
Exp. 1: 52 pairs of observations			
Boars castrated at 90.8 kg			
TL	.81	.61	.81
TWH	.81	.61	.81
Castration age	.42	.41	.43
Boars castrated at 225 d of age: 49 pairs of observations			
TL	.77	.71	.80
TWH	.83	.72	.84
Castration wt	.55	.34	.52
Exp. 2: 90 pairs of observations			
TL	.76	.60	.77
TWH	.78	.56	.79
Castration wt	.64	.52	.63
Exp. 3: 48 pairs of observations			
TL	.82	.68	.81
TWH	.80	.60	.79
Castration wt	.51	.51	.52
Exp. 4: 90 pairs of observations			
TL	.93	.83	.93
TWH	.92	.82	.92
Castration wt	.70	.74	.71

[a]Pooled within line correlations for Exp. 1. Remaining correlations are pooled within line and castration age. All correlations are significant (P<.01).

For boars castrated at a standard weight (90.8 kg), there was a positive correlation between age and testes weight. As the older boars would be the slower growing ones, this implies that the slower growing boars have heavier testes at a standard body weight. Presumably at a standard weight, the older boars are physiologically more mature. For boars castrated at a standard age, the correlations between body weight at castration and testes weight are also positive (.51 to .70). As heavy boars at a standard age would be the faster growing ones, this implies that faster growing boars have heavier testes at a standard age. This is likely caused by the part-whole relationship of testes weight to body weight.

Correlations of testes weights and in situ measurements at the time of castration ranged from .76 to .93, and suggest that in situ measurements can be used to predict excised testes weights. Correlations of .55 and .56 of testes width and testes length with the percentage of seminiferous tubules with active spermatogenesis suggest that young boars with larger testes measurements are expected to be more advanced with regard to sexual maturation.

Testicular traits appear to have desirable correlations with reproductive performance of female relatives. Correlations involving the mean performance of full sisters (ORFS and APFS) can be evaluated by the formula $r_{FS} = \frac{1}{2} h_1 h_2 r_G na$, where n is the harmonic mean of the number of full sisters/boar, a is the standard partial regression of the phenotypic mean of a family on an individual observation, h_1 is the square root of heritability for the female trait and h_2 the square root of heritability for the testes measurement. Heritability estimates of .45 and .40 for ovulation rate and age at puberty, respectively, have been observed (Young et al., 1978; Cunningham et al., 1979). If the heritability of testes weight is between .3 and .6, the estimated genetic correlation, r_G, between ovulation rate and testes weight ranges from .56 to .39 and .65 to .46 for Exp. 1 and 2, respectively. The correlations between testes measurements and female traits were not significant and the standard errors of estimates

TABLE 10. CORRELATIONS OF MEASURES OF TESTES SIZE AND CASTRATION WEIGHT WITH HISTOLOGICAL TRAITS[a]

Testes measurement[b]	Histological traits[c] SPERM	TUBDIA	LUMPER
TL	.55	.60	.52
TWH	.56	.61	.54
TW	.57	.59	.50
EW	.38	.47	.31
TTW	.55	.58	.48
Castration wt	.29	.36	.30

[a]Correlations are pooled within line and castration age (85 boars). All correlations are significant (P<.01).

[b]TL = in situ testes length, TWH = in situ testes width, TW = testes weight, EW = epididymides weight and TTW = testes + epididymides weight.

[c]TUBDIA, SPERM and LUMPER = seminiferous tubule diameter, percentage of tubules with active spermatogenesis and percentage of tubules with a lumen, respectively.

TABLE 11. CORRELATIONS OF FEMALE REPRODUCTIVE TRAITS AND THE BOARS BACKFAT PROBE WITH TESTES MEASUREMENTS[a]

Testes measurement[b]	Female reproductive traits and boar's backfat[c]							
	ORFS	DAMOR	APFS	DAMPUB	NBORNI	NBORN	NWEAN	BACKFAT
				Experiment 1				
TW	.15 (47)[d]		.06 (44)		.13 (99)	.02 (102)		.20* (102)
EW	.26 (47)		.07 (44)		.19 (99)	.10 (102)		.05 (102)
TTW	.18 (47)		.04 (44)		.14 (99)	.0 (102)		.18 (102)
				Experiment 2				
TW	.19 (65)	.03 (86)	−.02 (78)	−.06 (86)		.16 (89)	.14 (89)	.08 (66)
EW	.15 (65)	−.08 (86)	−.14 (78)	−.12 (86)		−.05 (89)	.02 (89)	.07 (66)
TTW	.19 (65)	.02 (86)	−.04 (78)	−.07 (86)		.14 (89)	.13 (89)	.08 (66)
L141	.26 (52)	−.15 (64)	−.03 (61)	−.25* (86)		−.05 (66)	−.01 (66)	.09 (66)
W141	.07 (52)	−.08 (64)	−.13 (61)	−.14* (86)		.11 (66)	.06 (66)	.11 (66)
				Experiment 3				
TW		.05 (35)		−.47* (18)		.14 (48)		.11 (48)
EW		.10 (35)		−.43* (18)		.03 (48)		.23 (48)
TTW		.06 (35)		−.48* (18)		.15 (48)		.13 (48)
L140		.13 (64)		−.14 (31)		.17 (95)		−.01 (95)
W140		.08 (64)		−.07 (31)		.14 (95)		−.09 (95)

	Experiment 4		
TW	−.11 (71)	.11 (71)	.03 (56)
EW	−.05 (71)	.05 (71)	−.04 (56)
TTW	−.11 (71)	.13 (71)	.02 (56)
SPERM	.10 (68)	.16 (68)	.03 (52)
TUBDIA	.05 (68)	.16 (68)	.03 (52)
LUMPER	.04 (68)	.11 (68)	−.04 (52)
L140	−.06 (51)	.03 (61)	.07 (52)
W140	−.15 (51)	.05 (61)	.07 (52)

[a]All correlations pooled within line and castration age.

[b]TW = testes weight, EW = epididymides weight, TTW = total testes weight, W140 or W141 = in situ testes width at 140 or 141 d of age. L140 or L141 = in situ testis length at 140 or 141 d of age, SPERM = percentage of seminiferous tubules with active spermatogenesis, TUBDIA = seminiferous tubule diameter and LUMPER = percentage of tubules with a lumen.

[c]ORFS = ovulation rate of full sibs, DAMOR = dam's ovulation rate, APFS = age at puberty of full sibs, DAMPUB = dam's age at puberty, NBORNI = number born in the dam's previous litter, NBORN = number born in the boar's contemporary litter, NWEAN = number weaned in the boar's contemporary litter, BACKFAT = backfat probe.

[d]Values in parentheses are number of observations.

*$P < .05$.

of r_G would be large. Correlations of testes weight with ovulation rate of dams were smaller than those with ovulation rate of sibs and equal $\frac{1}{2} h_1 h_2 r_G$, assuming no maternal covariance. The correlations between testes weights and size of dam's previous litter (NBORNI) are influenced less by maternal effects than correlations of testes weights and size of litter in which a boar is born. These and the correlations of measurements of testes size with size of litter a boar is born in, age at puberty of full sibs, and dam's age at puberty suggest that testes size may be related to female reproductive performance.

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