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Introduction

Little information is available on breed differences and variation in testicular development of young beef bulls. Larger testis size in young bulls is favorably correlated with sperm output, age at puberty, mature testicular size, and pregnancy rate. If testicular size is to be considered in selection programs for young sires, the breed differences, heritabilities, and relationships of testicular measurements to age and body weight must be established for young beef bulls.

The objectives of this study were to measure and define breed differences and variations in testicular size of yearling beef bulls, determine the heritability of yearling testicular size, and to examine the relationships between testicular size and age, growth traits, and age-of-dam effects in yearling beef bulls.

Procedure

Data were collected on a total of 3,090 yearling beef bulls of 12 breed groups finishing growth-performance tests in 1979 through 1983. Breeds were Limousin (L), Hereford (H), Charolais (C), Angus (A), Red Poll (R), Simmental (S), Pinzgauer (P), Brown Swiss (B), Gelbvieh (G), and three composite populations of the following breed composition: Composite I (1/4 L, 1/4 B, 1/4 C, 1/4 HxA), Composite II (1/4 G, 1/4 S, 1/4 H, 1/4 A), and Composite III (1/4 P, 1/4 R, 1/4 H, 1/4 A). All bulls were born as contemporaries in early spring of each year, weaned at approximately 200 days of age, and placed on a growth-performance test through 368 days of age. Birth weight, weaning weight, and 228-, 284-, 340-, and 356-day weights were recorded. At approximately one year of age (354.0 ± .4 days of age), scrotal circumference, length of each testicle, body weight, and hip height were measured on all bulls.

Scrotal circumference (SC) was assumed to represent the circumference of two apposed circles of equal radius (r), using the formula $SC = 4r + 2\pi r$. Average testicular length (average TL) was calculated by adding left TL and right TL and dividing by two. Paired testicular volume (PTV), assuming each testicle was a prolate spheroid, was then calculated using the formula:

$$PTV = .0396125 \text{ (Average TL)(SC)}^2$$

Data were analyzed by least squares procedures using a model that included breed group, sire/breed group, year, age of dam, and appropriate interactions. Paternal half-sib analysis (307 sires with approximately ten sons per sire) was used to estimate genetic parameters. Data expressed on an age-constant or weight-constant basis were adjusted to 354 days of age or to 919 lb liveweight (average of all bulls at yearling measurement) using the appropriate linear regression coefficients within breed group.

Results

Number of bulls per breed group and the least-squares breed group means and heritability estimates for body weight and hip height are shown in Table 1. Least-squares breed group means and heritability estimates for scrotal circumference, average testicular length, and paired testicular volume are given in Table 2. Breed group, sire/breed group, year, and age-of-dam effects were highly significant for all traits at a constant age (354 days) and constant body weight (919 lb), except that age-of-dam had no significant effect ($P>.25$) on hip height at constant body weight. Paternal half-sib estimates of heritability (h^2 ± SE) were high for age constant testicular traits, particularly for scrotal circumference (.41 ± .06). The lower heritability estimates for testicular length probably reflect experimental procedure rather than biological fact, since testicular length was more difficult to measure accurately than was scrotal circumference, and repeatability of scrotal circumference measurements is very high (>.90). The heritability estimate for scrotal circumference is in good agreement with the heritabilities of .26 to .78 reported for young Holstein bulls between 6 and 17 months of age and the .40 ± .15 to .69 ± .15 reported for beef bulls in other studies. Heritability estimates were slightly, but not significantly, higher for weight-constant testicular traits than for age-constant traits. Since body weight varied considerably at 354 days of age, weight-constant traits were adjusted to a much greater extent and may be less reliable estimates of heritability than are age-constant estimates.

Scrotal circumference, average testicular length, and paired testicular volume were larger ($P<.01$) for Pinzgauer, Simmental, Brown Swiss, and Gelbvieh than for other pure breeds and were smaller ($P<.01$) for Limousin and Hereford than for all other breed groups at 354 days of age (Table 2). The ranking of purebred means for scrotal circumference (Table 2) was similar to the rankings of Limousin, Hereford, Charolais, Angus, and Simmental that have been reported in other studies. Although significant breed differences existed (Table 2), considerable variation in these testicular traits existed within each breed. The range within each breed was large enough that the range for Limousin bulls overlapped that of Gelbvieh and that of all intermediate pure breeds. This variation, coupled with the relatively high estimates of heritability for testicular traits, indicates that rapid improvement in yearling testicular size can be achieved by selection. Such selection should also result in rapid improvement in age at puberty and favorably affect other reproductive characteristics.

Age-constant genetic and phenotypic correlations between a variety of body growth traits and testicular traits in yearling beef bulls were generally positive but were relatively small (Table 3). Those genetic correlations that were negative had values that were essentially equal to zero. The linear effects of age and yearling body weight each affected testicular traits when analyzed as separate covariates ($P<.001$), but age continued to have a highly significant effect on testicular traits when adjusted for body weight. These data suggest that adjustment of testicular traits for age differences would be more important than adjustment for differences in growth traits, both among and within breeds of yearling beef bulls. These results also indicate that body growth traits and testicular size in yearling beef bulls are favorably related, genetically, but the low level of the relationship indicates that testicular size and body weight are largely independent (Table 3). In other words, selection of beef bulls for growth traits would have little effect on yearling testicular size, and selection for testicular size would have little effect on yearling weight.

Age of dam had a significant effect on age-constant testicular traits of yearling beef bulls (Table 4), and testicular size increased as age of dam increased. The effect of age of dam on testicular traits remained significant after adjustment of data to a constant body weight, which should have corrected for documented age-of-dam effects, such as differences due to lactation. Testicular size of yearling beef bulls from two-year-old dams was smaller, on an age-constant ($P<.01$) and weight-

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constant (P<.05) basis, than that of bulls from older dams, suggesting that testicular development is delayed by undefined *in utero* or preweaning factors influencing the male offspring of first-calf dams. Age-of-dam effects on testicular traits were similar among the breed groups examined in this study, indicating that a single adjustment for age of dam should be appropriate, regardless of breed.

Bull age at the time that yearling testicular measurements were obtained ranged from 300 to 400 days of age in this study. Adjustment factors that we recommend for testicular traits of beef bulls within that age range are shown in Table 5. To adjust a testicular trait to 365 days of age, the linear regression coefficients for scrotal circumference (cm/day), average testicular length (cm/day), and paired testicular volume (cm^3/day) are given, since they offer a simple, yet effective, method for adjusting testicular size to a constant age. The linear regression coefficients for testicular traits were uniformly positive in all breed groups. However, least-squares analysis of variance indicated no significant difference among breeds in their linear regression coefficients for these testicular traits. Therefore, we recommend using only the adjustment factor (linear regression coefficient) shown for "all bulls", regardless of breed, rather than using any of the adjustment factors shown for individual breed groups (Table 5). The age-of-dam adjustment factors are not multiplicative, and these age-of-dam constants should be added to the testicular trait only after the trait has been adjusted to 365 days of age (Table 5).

Table 1.—Least-squares means and heritability (h^2) estimates for body weight and hip height of yearling beef bulls

Breed group	No. of bulls	Body weight[a] (lb; SE = ± 7) 354 days	Body weight[a] 919 lb	Hip height[b] (in; SE = ± 0.1) 354 days	Hip height[b] 919 lb
Limousin	222	875	49.1	49.6	
Hereford	256	791	45.2	46.7	
Charolais	197	993	50.3	49.5	
Angus	449	825	45.8	46.9	
Red Poll	222	835	47.2	48.1	
Pinzgauer	144	959	48.8	48.3	
Simmental	238	1009	50.8	49.8	
Brown Swiss	245	964	50.3	49.8	
Gelbvieh	233	970	50.0	49.5	
Composite I	245	971	49.6	49.1	
Composite II	488	967	48.7	48.2	
Composite III	151	924	47.8	47.7	
h^2 ± SE	(3,090)[c]	.32 ± .05	.28 ± .05	.34 ± .06	

[a]Breed means that differ by >35 lb body weight are different (P<.01).
[b]Breed means that differ by >.4 in hip height are different (P<.01).
[c]Total bulls represented 307 sires with approxmiately 26 sires/breed group and sons/sire.

Table 2.—Least-squares means and heritability (h^2) estimates for scrotal circumference (SC), average testicular length (TL), and paired testicular volume (PTV) of yearling beef bulls[a]

Breed group	SC (cm; SE = ±.3) 354 days	SC 919 lb	Ave. TL (cm; SE = ±.1) 354 days	Ave. TL 919 lb	PTV (cm^3; SE = ±10) 354 days	PTV 919 lb
Limousin	28.8	29.1	9.5	9.7	318	337
Hereford	30.1	32.1	9.4	10.2	342	410
Charolais	31.4	30.4	10.0	9.5	401	358
Angus	31.9	33.2	10.3	10.8	421	474
Red Poll	32.3	33.5	10.2	10.6	427	476
Pinzgauer	33.4	33.0	10.9	10.7	488	473
Simmental	33.4	32.4	11.1	10.8	497	456
Brown Swiss	33.5	32.9	11.4	11.1	512	485
Gelbvieh	33.6	32.9	11.2	11.0	509	479
Composite I	32.2	31.7	10.9	10.7	456[b]	435
Composite II	33.5	33.3	11.3	11.1	519[b]	496
Composite III	33.4	33.3	10.7	10.7	476[b]	474
h^2 ± SE	.41 ± .06	.50 ± .06	.34 ± .06	.39 ± .06	.37 ± .06	.45 ± .06

[a]Breed means that differ by >1.0 cm (SC), >.3 cm (Ave. TL), or >48 cm^3 (PTV) are different (P<.01).
[b]The effect of heterosis on age-constant PTV was +13.1 percent, +17.4 percent and +13.3 percent in Composite I, II, and III, respectively.

Table 3.—Genetic and phenotypic correlations between body weight traits during development and age-constant (354 days) testicular traits

Body weight trait	Yearling testicular trait: Scrotal circumference	Ave. testicular length	Paired testicular volume
	Genetic correlations		
Birth weight	−.02 ± .10	−.01 ± .11	−.05 ± .11
Weaning weight	.00 ± .10	.19 ± .10	.11 ± .10
AGD (Birth to weaning)[a]	.02 ± .11	.21 ± .11	.14 ± .11
Yearling weight	.10 ± .11	.16 ± .11	.14 ± .12
ADG (weaning to yearling)[a]	.00 ± .10	−.02 ± .11	−.04 ± .11
	Phenotypic correlations		
Birth weight	.10	.08	.11
Weaning weight	.26	.24	.28
ADG (Birth to weaning)[a]	.25	.24	.28
Yearling weight	.33	.28	.34
ADG (Weaning to yearling)[a]	.20	.15	.19

[a]Average daily gain (ADG).

Table 4.—Age-of-dam means for testicular traits of yearling beef bulls

Age of dam (yr)	No. of bulls	Yearling testicular trait: Scrotal circumference (cm)	Ave. testicular length (cm)	Paired testicular volume (cm^3)
		Age constant (354 days)		
2	831	31.6 ± .1	10.2 ± .1	415 ± 6
3	757	32.1 ± .1[a]	10.6 ± .1[a]	443 ± 5[a]
4	502	32.5 ± .1[a]	10.7 ± .1[a]	460 ± 6[a]
>4	1,000	32.9 ± .1[a]	10.8 ± .1[a]	471 ± 5[a]
>2	2,259	32.6 ± .1[a]	10.7 ± .1[a]	459 ± 4[a]
Total	3,090	32.3 ± .1	10.6 ± .1	447 ± 3
		Weight constant (919 lb)		
2	831	32.1 ± .1	10.4 ± .1	433 ± 6
3	757	32.3 ± .1	10.6 ± .1[b]	446 ± 5
4	502	32.4 ± .1[b]	10.7 ± .1[b]	452 ± 6[b]
>4	1,000	32.6 ± .1[b]	10.6 ± .1[b]	454 ± 5[b]
>2	2,259	32.5 ± .1[b]	10.6 ± .1[b]	451 ± 4[b]
Total	3,090	32.3 ± .1	10.6 ± .1	446 ± 4

[a b]Means within a column differ from the mean of bulls from 2-year-old dams ([a]$P<.01$; [b]$P<.05$).

Table 5.—Adjustment factors for the effects of bull age and age of dam on testicular traits in yearling beef bulls between 300 and 400 days of age

Adjustment	Adjustment factors for testicular traits: Scrotal circumference	Ave. testicular length	Paired testicular volume
For bull age[a]:	(±SE per breed group = ±.012)	(±SE per breed group = ±.006)	(±SE per breed group = ±.40)
Limousin	.026 cm/day	.014 cm/day	1.13 cm^3/day
Hereford	.036	.012	1.26
Charolais	.013	.009	.73
Angus	.034	.013	1.44
Red Poll	.035	.016	1.59
Pinzgauer	.034	.017	1.65
Simmental	.034	.011	1.54
Brown Swiss	.032	.014	1.59
Gelbvieh	.026	.006	1.06
Composite I	.054	.021	2.25
Composite II	.030	.013	1.62
Composite III	.028	.012	1.32
All bulls[b]	.032 cm/day	.013 cm/day	1.43 cm^3/day
For age of dam[c]:			
5-yr or older dams	+ 0.0 cm	+ 0.0 cm	+ 0 cm^3
4-yr-old dams	+ 0.4 cm	+ 0.1 cm	+ 11 cm^3
3-yr-old dams	+ 0.8 cm	+ 0.2 cm	+ 28 cm^3
2-yr-old dams	+ 1.3 cm	+ 0.6 cm	+ 56 cm^3

[a]Adjustment factors are linear regression coefficients (cm or cm^3 per day of age).
[b]Use of this adjustment factor (linear regression coefficient) only, regardless of breed, is recommended. Use the following formula to adjust a trait to 365 days of age: Adjusted testicular trait = [(Adjustment factor) (365 − Actual bull age in days) + (Actual measurement)].
[c]These age-of-dam constants should be added to the testicular trait only after the trait has been adjusted to 365 days of age.