www.canadianveterinarians.net/larounds

Large Animal VETERINARY Rounds™

APRIL 2004
Volume 4, Issue 4

AS PRESENTED IN THE ROUNDS OF THE DEPARTMENT OF LARGE ANIMAL CLINICAL SCIENCES OF THE WESTERN COLLEGE OF VETERINARY MEDICINE, UNIVERSITY OF SASKATCHEWAN

Pubertal development of *Bos taurus* bulls

By Albert D. Barth, DMV, and Leonardo F.C. Brito, DMV

Pressure to improve the growth traits of beef cattle has resulted in the selection and use of younger bulls in an effort to shorten generation intervals. However, variability in the onset of puberty, among and within breeds, has resulted in great variability in the reproductive performance of young bulls. Poor reproductive performance by yearling bulls may be partly due to an inadequacy in mating ability; however, semen quality and quantity are probably more important factors. An understanding of pubertal changes and the factors that affect pubertal development is required in order to promote the successful use of yearling bulls for reproductive purposes. These factors are discussed in this issue of *Large Animal Veterinary Rounds*.

Developmental changes in the testes

Testicular development and the establishment of spermatogenesis has been described in Holstein bulls.[1] The seminiferous cords that become tubules occupy 44% of the testicular parenchyma at 3 months and 81% at 8 months. A lumen is established in the seminiferous cords by about 5 months and spermatogenesis by about 8 months. The weight of a pair of testes increases from 9±1 g at 3 months to 117±10 g at 8 months of age. In comparison, at 12 months, the weight of a pair of testes with a scrotal circumference of 33.5 cm is about 500 g and it increases linearly at about 37 g/cm.[2] Figure 1 depicts the histological development of the testes from 2 to 10 months of age.

An initial rise in follicle stimulating hormone (FSH) from age 3 to 5 months results in a proliferation of Sertoli cells, a lengthening of the seminiferous tubules, and an increase in tubule diameter. At the same time, there is a rise in luteinizing hormone (LH) secretion resulting in increased testosterone production by the Leydig cells. From 5 to 8 months of age, FSH and LH remain low, rising again with the onset of puberty. It has been demonstrated that the greater the rise in LH at age 3 to 5 months, the earlier the onset of puberty, and the larger the size of the testes at age 12 months.[3] Poor health or environmental conditions that interfere with the growth of calves during this critical period are speculated to delay puberty and reduce testis size in the yearling bull. This may explain why bulls raised by heifer mothers, and presumably receiving less milk, have smaller than average testes at 12 months old.[4]

Relationships of age and puberty

Testis growth is very rapid and almost linear from 7 to 12 months of age and declines after 12 months.[5] Between age 7 and 12 months, the scrotal circumference increases at a rate of 0.06–0.07 cm/day.[5,6] By age 24 months, the testes will be approximately 90% of the mature size.[7]

Onset of puberty has been defined as the first time the ejaculate contains at least 50×10^6 sperm with at least 10% having progressive motility.[8] Several studies have shown that the age at onset of

WCVM
Western College of Veterinary Medicine

Department of Large Animal Clinical Sciences
Western College of Veterinary Medicine

Jonathan M. Naylor, DVM, Diplomate ACVIM *(Editor)*
Charles S. Rhodes, DVM, MSc *(Dean)*
David G. Wilson, DVM, Diplomate ACVS *(Acting Dept. Head)*

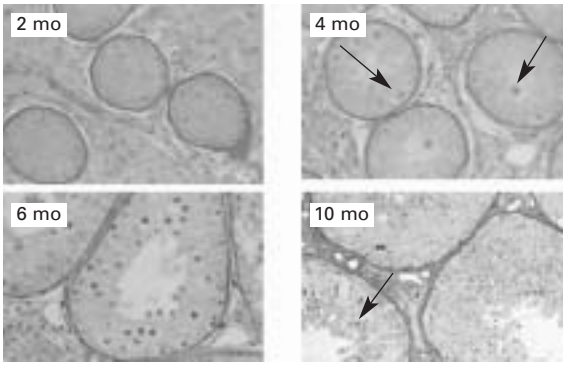
Ken Armstrong, DVM, Professor Emeritus
Sue Ashburner, DVM
Jeremy Bailey, BVSc, Diplomate ACVS
Spence M. Barber, DVM, Diplomate ACVS
Albert D. Barth, DVM, Diplomate ACT
Frank Bristol, DVM, DACT, Professor Emeritus
Ray Butler, DVM, Professor Emeritus
John Campbell, DVM, DVSc
Claire Card, DVM, DACT
Terry D. Carruthers, DVM, PhD
Bill Cates, DVM, Professor Emeritus
Chris Clark, VetMB, MVetSc
Peter B. Fretz, DVM, Diplomate ACVS, Professor Emeritus
Paul Greenough, DVM, Professor Emeritus
Jerry Haigh, DVM, Diplomate ACZM
Steve Manning, DVM, Diplomate ACT
Reuben J. Mapletoft, DVM, PhD
Kelly MacLellan, DVM
Colin Palmer, DVM, Diplomate ACT
Andre Palasz, MSc, PhD
Jag Patel, DVM, Diplomate ACT
Lyall Petrie, BVMS, PhD
O.M. Radostits, DVM, Diplomate ACVIM, Professor Emeritus
Fritz J. Schumann, DVM, MVetSc
Joseph M. Stookey, PhD
Hugh G.G. Townsend, DVM, MSc
Cheryl Waldner, DVM, PhD
Murray R. Woodbury, DVM, MSc

Western College of Veterinary Medicine
Department of Large Animal Clinical Sciences
52 Campus Drive
University of Saskatchewan
Saskatoon, Saskatchewan S7N 5B4

The editorial content of *Large Animal Veterinary Rounds* is determined solely by the Department of Large Animal Clinical Sciences, Western College of Veterinary Medicine

The Canadian Veterinary Medical Association recognizes the educational value of this publication and provides support to the WCVM for its distribution.

Figure 1: Histological development of the testes from 2 to 10 months-of-age in bulls



Testis seminiferous cords occupy a small proportion of the testicular parenchyma at 2 months and only a few germinal stem cells can be observed within the cords. Seminiferous cords increase in length and diameter, a lumen begins to develop, germinal stem cells migrate toward the basement membrane (arrows upper right), and upon arrival initiate spermatogenesis at 4 months. By 6 months, a seminiferous tubule lumen is fully developed and different cell types of the spermatogenic line can be observed, including spermatogonia, spermatocytes, and spermatids. The first fully formed sperm (arrow lower right) appear at about age 10 months.

puberty varies from 231 to 371 days.[9-11] Pubertal bulls produce a high number of sperm with a variety of abnormalities. The time from onset of puberty until semen quality attains satisfactory adult levels (>60% sperm motility and >70% normal sperm morphology) is 3 to 4 months.[12] Studies at the Western College of Veterinary Medicine (WCVM) indicate that approximately 33% and 60% of beef bulls produce satisfactory quality semen at 12 and 14 months of age, respectively, and that most bulls will have satisfactory semen quality and are considered mature by 16 months of age.[13,14]

Effect of nutrition on sexual development:

High-energy diets with adequate protein, vitamins, and minerals may hasten the onset of puberty in bulls. There appears to be only 1 published study about the effect of calfhood nutrition on pubertal development. In this study, Holstein bull calves were raised on low-, medium-, and high-energy rations from 1 to 80 weeks of age and semen was collected at 14-day intervals (Table 1).[15]

This study demonstrated that restriction of energy intake in calves had a marked effect on pubertal development. Since later-maturing bulls have a smaller rise in LH at age 3 to 5 months than early-maturing bulls,[3] it would seem likely that nutritional restriction in the preweaning period is detrimental to early attainment of puberty.

Table 1: Effect of dietary energy on age of onset of puberty in bulls[15]

	Dietary energy		
	Low	Medium	High
Age (weeks) at puberty	57	49	43
Weight at puberty (kg)	252	288	330
Number of ejaculates up to 80 weeks	12	14	19
Sperm per ejaculate (billion)	2.3	3.8	3.7
60-90 day pregnancy rates (%)	74.1	72.9	74.2

Furthermore, since bull calves raised to weaning age by heifer mothers have smaller testes at 1 year than those raised by cow mothers,[4] it would seem likely that puberty is delayed by preweaning nutritional restriction regardless of good postweaning nutrition.

Results of recent studies at WCVM (data not published) demonstrate that early-weaned beef calves receiving low nutrition after age 2 months have retarded testis development and delayed puberty. Physiological and stimulated LH (gonadotropin-releasing hormone [GnRH]), and testosterone serum concentrations are reduced in these calves, demonstrating that restricted nutrition suppresses the hypothalamic GnRH pulse-generator and decreases pituitary responsiveness to GnRH. Serum testosterone concentrations are decreased secondary to reduced LH concentrations, possibly due to direct effects on function and/or number of Leydig cells. Therefore, delayed sexual development in bulls receiving restricted nutrition during the preweaning period results from inhibition of the hypothalamus-pituitary-gonad axis. Strategies to improve nutrition for bull calves raised by heifers during the preweaning period may hasten sexual development and possibly improve fertility in yearling bulls.

Different levels of nutrition after weaning (in calves with similar preweaning nutrition) appear to affect the rate of testicular growth; however, it is not clear whether age of onset of puberty is also affected.[16-20] Apparently, high-energy intake up to about age 12 months in beef bulls does not impair future semen quality provided that rations from 1 to 2 years of age do not result in fattening.[16] However, in one study,[17] beef bulls fed a high-energy diet from 6 to 11.5 months of age had lower semen quality than bulls on a lower-energy diet and the lower semen quality was likely due to the accumulation of fat in the scrotum.[18] These studies appear to indicate that larger scrotal circumferences at 1 year in bulls fed for maximal growth are due to hastened testis development, but in some cases, may be partly due to excess fat deposition in the scrotum. In 2 other

studies using feeding periods that lasted until age 15 months, scrotal circumference was larger and testis histology was similar at the end of the trials. However, semen quality was lower in bulls on high-energy diets compared to those on low-energy diets.[19,20] Thus, the likelihood of scrotal fat accumulation leading to disturbed spermatogenesis in bulls on high-energy diets increases in proportion to the amount of time the bulls are fed such diets.

High-energy diets may have other detrimental effects as well. There is evidence that excessive energy intake in young bulls may result in abnormal foot growth due to laminitis, as well as abnormal bone and cartilage growth.[21] In addition, high-energy diets increase the risk of rumen inflammation, liver abscess, and vesicular adenitis.[22]

Effect of breed on age at onset of puberty

Significant genetic variations exist between breeds of cattle for age of puberty.[23] In general, faster-gaining and larger mature size breeds reach puberty at a greater weight than slower-gaining breeds of smaller size. Beef breeds historically selected for milk production (eg, Braunvieh, Gelbvieh, Red Poll, Pinzgauer, and Simmental) reach puberty at significantly younger ages than breeds not selected for milk production (eg, Charolais, Limousin, and Hereford). In general, the large milk-producing beef breeds have an earlier onset of puberty and have larger testes at an early age and at maturity, than smaller breeds of cattle with lower milk production. Holstein-Friesian heifers reach puberty at an age similar to heifers of the large milk-producing beef breeds.[24] Although direct comparisons for age at puberty in bulls of dairy and beef breeds have not been made, heifer ages at puberty and mean age at puberty of Holstein-Friesian bulls[10,11] suggest that the age of puberty in Holstein-Friesian bulls is comparable to bulls of the large beef breeds historically selected for milk production.

There are great differences between breeds of bulls and testis size at any given age.[25] In double-muscled bulls, testes weight at 12 months-of-age was 14% less than in normally-muscled bulls, however, the effect of double muscling on age at maturity has not been reported.[26] There is considerable evidence that scrotal circumference between 1 and 2 years-of-age is moderately to highly heritable.[4,27,28] Therefore, breeders could make rapid progress in selection for testis size and consequently, age at maturity.

Effect of season on onset of puberty

The effect of photoperiod on reproduction has been characterized for many species.[29] Although cattle do not have distinctly seasonal reproductive activity, there is evidence of seasonal effects in bovine reproduction. For example, a return to estrous cycles takes longer in cows that calve in winter than those that calve in summer.[30] The timing of puberty onset is also influenced by season of birth. In Wisconsin, heifers born in September were younger at puberty than those born in March. In addition, heifers reared in environmental chambers from age 6 months and exposed to summer (spring to fall) conditions were younger at puberty than heifers exposed to winter (fall to spring) conditions.[31] Photoperiod most likely plays a role in these responses since, in another experiment, heifers given supplemental light in autumn were younger at puberty than those exposed to natural light.[32]

Season of birth appears to influence puberty in bull calves as well. In a western Canadian study, LH pulse amplitude was significantly lower from 1 to 6 months of age in autumn-born calves than in spring-born calves, and age at puberty had greater variability in autumn-born bulls.[33] Photoperiod may also have an effect on semen quality since seasonal variations in LH and testosterone secretion have been reported in bulls.[33-37] In 4 Norwegian Red bulls, blood testosterone levels were significantly lower in October and December than in February, June, and August.[35] In a recent WCVM study (unpublished data), LH and testosterone secretions were lower in fall and winter and higher in spring and summer. Adequate levels of blood and testis tissue testosterone are known to be important for normal spermatogenesis.[34,38] In 2110, mature, western Canadian range bulls, semen quality was lowest in fall and winter and highest in spring and summer.[39] Since semen quality in these bulls improved in the spring when they were still on the same winter feed supplies, differences in semen quality may have been due to either milder weather conditions or increasing photoperiod.

Relationship of scrotal circumference to puberty

Negative correlations (r) as high as 0.9 have been observed between scrotal circumference, bull age at puberty, and age at puberty in half-sibling heifers.[40,41] Larger scrotal circumference in sires was associated with earlier age of puberty in heifer offspring ($r = -0.98$).[42] These very strong relationships likely indicate that age at puberty and scrotal circumference have a common genetic origin. There is good evidence that heterosis in cattle for traits related to size and age at puberty in females, and scrotal circumference in males is due to dominant genes.[23] Furthermore, in 2 studies, correlations of 0.66 and 0.97 were found between breed means for scrotal circumference and fertility of female offspring.[23,43]

Table 2: Relationship of scrotal circumference with percentage of bulls that had onset of puberty[8]

Onset of puberty	Scrotal circumference
32 %	27 cm
52 %	28 cm
74 %	29 cm
97 %	30 cm

Scrotal circumference may be a better indicator of puberty than either age or weight, regardless of breed.[8] In a group of 31 bulls comprised of several breeds, age at puberty varied by 62 days among breeds and by 88 days among bulls. However, breeds did not differ in scrotal circumference at onset of puberty. Scrotal circumference at onset of puberty averaged 27.9 ± 0.2 cm and ranged from 25.9 to 30.1 cm (Table 2).

Selection of bulls at weaning.

The first opportunity for selection and culling of bulls is after weaning when they are 6- to 8-months-old. At this age, only a few calves clearly display undesirable conformational attributes and the main criterion for selection is testicular development. Bulls that are unlikely to reach the minimum desired scrotal circumference by age 12 months might be castrated and sold, or fed as steers.

Some studies have indicated that scrotal circumference at weaning is useful for predicting scrotal circumference at 1 year of age.[44,45] However, a study involving 708 bulls fed in a record of performance (ROP) station in western Canada, indicated that scrotal circumference at weaning was not reliable for predicting yearling scrotal circumference.[6] Using the guidelines of the Western Canadian Association of Bovine Practitioners, 59% to 91% of all ROP bulls, depending on breed, achieved the minimum suggested scrotal circumference at age 1 year. A large portion of these bulls met the minimum requirement at 365 days of age even though they had well-below the minimum suggested scrotal circumference at 240 days. Therefore, weaning scrotal circumference should not be used as a culling tool. On the other hand, bulls with a scrotal circumference measurement ≥1 standard deviation above the mean at 240 days of age had a high likelihood of achieving the minimum requirement for scrotal circumference at 365 days. Therefore, weaning scrotal circumference could be used as a tool for selecting bulls with a high probability of achieving the minimum scrotal circumference at 1 year.

Table 3: Mean scrotal circumference (cm) of 12-month-old bulls determined from 6 studies in Canada and the USA[25]

Simmental	34.5	Red Poll	32.7	Hereford	31.9
Brown Swiss	33.8	Charolais	32.6	Salers	30.9
Pinzgauer	33.7	Maine Anjou	32.6	Galloway	30.6
Gelbvieh	33.6	Shorthorn	32.2	Limousin	30.0
Angus	33.3	Tarentaise	32.0	Blonde d'Aquitaine	29.5

Selection of bulls at 1 year of age

Final selection of bulls for breeding potential can be done when bulls are 12-16 months old. This is the period when puberty is ending and the rapid testicular development of previous months tapers off. At 14 and 15 months of age, about 60% and 80% of bulls, respectively, will be sexually mature (able to produce semen with satisfactory quality).[14] However, yearling bulls with a small scrotal circumference at age 1 year, still had a small scrotal circumference at 2 years old.[5]

Several studies have indicated that the fertility of yearling bulls is not significantly lower than that of older bulls.[46-49] Producers wishing to use yearling bulls should select bulls with early birth dates, good sex drive, and normal mating ability. Scrotal circumference should be above-average for age and breed and a semen evaluation must be performed to ensure that the pubertal period has passed.

Table 3 shows recent scrotal circumference data from 6 studies of bulls in ROP stations.[25] Data were corrected to 365 days of age using a factor of 0.06 cm/day of age for bulls <365-days-old and 0.04 cm/day of age for bulls >365-days-old. For example, the mean scrotal circumference for a Simmental bull at 365-days-old is 34.5 cm; while a 335-day-old Simmental bull should average 30 × .06 = 1.8 cm less. The mean scrotal cricumference in a Limousin bull that is 20 days older than 1 year should average 20 × .04 cm = 0.8 cm larger than the mean of 30.0 cm.

The minimum recommendations for scrotal circumference in Table 4 eliminates bulls in approximately the bottom 15% for most breeds. In some of the breeds, the cut-off suggested is somewhat more than 15% to increase selection pressure.[25]

Summary

In summary, it is desirable to select bulls for early puberty to increase the probability of their usefulness as breeding bulls at 14 to 16 months of age. In addi-

Table 4: Suggested minimum scrotal circumference (cm) for common beef breeds at different ages[25]

Age Mo.	Simmental, Gelbvieh, Pinzgauer, Brown Swiss	Charolais, Angus, Maine Anjou, Red Poll, Holstein, South Devon	Hereford, Salers, Shorthorn, Tarentaise	Limousin, Blonde d'Aquitaine, Galloway
12	32	31	30	29
13	33	32	31	30
14	34	33	32	31
15-20	35	34	33	32
21-30	36	35	34	32

tion, these bulls will produce earlier-maturing daughters that have a greater probability for high lifetime-productivity than later-maturing females. Those involved in assisting producers in the selection of bulls must have a good understanding of the factors that influence sexual development. Two very important factors influencing age at puberty include breed and calfhood nutrition. Season of birth may have important effects, however, this is not well investigated. Bulls with a high probability of having large testes at age 1 year may be selected as early as the time of weaning; however, culling due to small testes at weaning is not a safe practice since a large proportion of bulls with less than average size testis at weaning will have adequate testis size at 1 year.

Dr. Leonardo Brito *graduated from the Federal University of Uberlandia, Brazil in 1997. He received an MSc degree in Animal Reproduction from the Sao Paulo State University, Brazil in 2000 and an MVetSc degree in Theriogenology from the WCVM in 2002. He is currently a PhD student at the WCVM.*

Dr. Albert Barth *graduated in 1971 and received an MVetSci degree in Theriogenology in 1978 from the WCVM. He has been a professor at the WCVM since 1978 and is a Diplomate of the American College of Theriogenologists.*

References

1. Curtis SK, Amann RP. Testicular development and establishment of spermatogenesis in Holstein bulls. *J Anim Sci* 1981;53:1645-1657.
2. Coulter GH, Keller DG. Scrotal circumference of young beef bulls: relationship to paired testes weight, effect of breed and predictability. *Can J Anim Sci* 1982;62:133-139.
3. Evans ACO, Davies FJ, Nasser LF, Bowman P, Rawlings NC. Differences in early patterns of gonadotrophin secretion between early and late maturing bulls and changes in semen characteristics at puberty. *Theriogenology* 1995;43:569-578.
4. Lunstra DD, Gregory KE, Cundiff LV. Heritability estimates and adjustment factors for the effects of bull age and age of dam on yearling testicular size in breeds of bulls. *Theriogenology* 1988;30:127-136.
5. Cates WF, Nicholson HH, Crow GH, Janzen ED. Testicular development in record of performance bulls. *Proceeding Ann Meeting Soc Theriogenology*. Spokane, Washington; 1981:16-30.
6. Barth AD, Ominski KH. The relationship between scrotal circumference at weaning and at one year of age in beef bulls. *Canadian Vet J* 2000;41:1-6.
7. Coulter GH. Puberty and postpubertal development of beef bulls. In: Morrow DA, ed. *Current Therapy In Theriogenology* Philidelphia, PA: WB Saunders; 1986:142-148.
8. Lunstra DD, Ford JJ, Echternkamp SE. Puberty in beef bulls: hormone concentrations, growth, testicular development, sperm production and sexual aggressiveness in bulls of different breeds. *J Anim Sci* 1978;46: 1054-1062.
9. Wolf FR, Almquist JO, Hale EB. Prepubertal behavior and pubertal characteristics of beef bulls on high nutrient allowance. *J Anim Sci* 1965;24:761-765.
10. Killian GJ, Amann RP. Reproductive capacity of dairy bulls. IX. Changes in reproductive organ weights and semen characteristics of Holstein bulls during the first thirty weeks after puberty. *J Dairy Sci* 1972;55:1631-1635.
11. Almquist JO, Branas RJ, Barber KA. Postpubertal changes in semen production of Charolais bulls ejaculated at high frequency and the relation between testicular measurement and sperm output. *J Anim Sci* 1976;42:670-676.
12. Lunstra DD, Echternkamp SE. Puberty in beef bulls: acrosome morphology and semen quality in bulls of different breeds. *J Anim Sci* 1982;55:638-648.
13. Cates WF. Observations on scrotal circumference and its relationship to classification of bulls. *Proc Soc Theriogenology*. Cheyenne. 1975:1-18.
14. Arteaga AA, Baracaldo M, Barth AD. The proportion of western Canadian beef bulls with mature spermiograms at 11 to 15 months of age. *Can Vet J* 2001;42:783-787.
15. Bratton RW, Musgrave SD, Dunn HO, Foote RH, Henderson CR. Semen production and fertility of young bulls raised on three different energy levels of feed intake. *J Anim Sci* 1956;15:1296-1297. Abstract.
16. Pruitt RJ, Corah LR, Stevenson JS, et al. Effect of energy intake after weaning on the sexual development of beef bulls. II Age of first mating, age at puberty, testosterone, and scrotal circumference. *J Anim Sci* 1986;63:579-585.
17. Mwansa PB, Makarechian M. The effect of post weaning level of dietary energy on sex drive and semen quality of young beef bulls. *Theriogenology* 1991;35:1169-1178.
18. Seidel GE Jr, Pickett BW, Wilsey CO, Seidel SM. Effect of high level of nutrition on reproductive characteristics of Angus bulls. Paper presented at: The 9th International Congress on Animal Reproduction and Artificial Insemination, Symposia III. Madrid, Spain. 1980: Abstract 359.
19. Ohl MW, Ott RS, Faulkner DB, et al. Effects of rate of gain on scrotal circumference and histopathologic features of the testes of half-sibling yearling beef bulls. *Am J Vet Res* 1996;57: 844-847.
20. Coulter GH, Carruthers TD, Amann RP, Kozub GC. Testicular development, daily sperm production and epididymal sperm reserves in 15-mo-old Angus and Hereford bulls: effects of bull strain plus dietary energy. *J Anim Sci* 1987;64:254-260.
21. Greenough PR, Vermunt JJ, McKinnon JJ, Fathy FA, Berg PA, Cohen RDH. Laminitis-like changes in the claws of feedlot cattle. *Can Vet J* 1990;31:202-208.
22. Dargatz DA, Mortimer RG, Ball L. Vesicular adenitis of bulls: a review. *Theriogenology* 1987;28:513-521.
23. Gregory KE, Lunstra DD, Cundiff LV, Koch RM. Breed effects and heterosis in advanced generations of composite populations for puberty and scrotal circumference traits of beef cattle. *J Anim Sci* 1991;62: 2795-2807.
24. Cundiff LV, Gregory KE, Koch RM, Dickerson GE. Genetic diversity among cattle breeds and use to increase beef production efficiency in a temperate environment. *Proceedings 3rd World Congress on Genet Appl to Livest Prod*. IX. Lincoln, NE. 1986:271-282.
25. Barth AD. Bull breeding soundness evaluation. Manual; The Western Canadian Association of Bovine Practitioners, Saskatoon, SK. 2000.
26. Michaux C, Hanset R. Sexual development of double-muscled and conventional bulls 1. Testicular growth. *Zeitschrift Fur Tierzuchtung und Zuchtungsbiologie* 1981;98:29-37.
27. Latimer FG, Wilson LL, Cain MF. Scrotal circumference measurements in beef bulls: heritability estimates, breed and test station effects. *J Anim Sci* 1982;54:473-479.

28. Coulter GH, Rounsaville TR, Foote RH. Heritability of testicular size and consistency in Holstein bulls. *J Anim Sci* 1976;43:9-12.
29. Rieter RJ. The pineal and its hormones in the control of reproduction in mammals. *Endocrine Rev* 1980;1:109-131.
30. Hansen PJ. Seasonal modulation of puberty and postpartum anestrus in cattle: a review. *Livest Prod Sci* 1985;12:309-327.
31. Schillo K, Hanson PJ, Kamwanja. LA Dierschke DJ, Hauser ER. Influence of season on sexual development in heifers: age at puberty as related to growth and serum concentrations of gonadotropins, prolactin, thyroxine and progesterone. *Biol Reprod* 1983;28:329-341.
32. Hansen PJ, Kamwanja LA, Hauser ER. Photoperiod influences age at puberty in heifers. *J Anim Sci* 1983;57:985-992.
33. Aravindakshan JP, Honaramooz A, Bartlewski PM, Beard AP, Pierson RR, Rawlings NC. Gonadotrophin secretion in prepubertal bull calves born in spring and autumn. *J Reprod Fertil* 2000;120:159-167.
34. Zirkin BR, Santulli R, Awoniyi CA, Ewing LL. Maintenance of advanced spermatogenic cells in the adult rat testis: quantitative relationship to testosterone concentration within the testis. *Endocrinology* 1989;124:2043-2049.
35. Sundby A, Tollman R. Plasma testosterone in bulls, seasonal variation. *Acta Vet Scand* 1978;19:263-268.
36. Phillipps RW, Bradford K Jr, Heemstra LC, Eaton ON. Seasonal variation in the semen of bulls. *Am J Vet Res* 1943;4:115-119.
37. Welsh TH Jr, Randel RD, Johnson BH. Interrelationships of serum corticosterioids, LH and testosterone in the male bovine. *Arch Androl* 1981;6:141-150.
38. Courot M, Hochereau de Reviers MT, Monet-Kuntz C, et al. Endocrinology of spermatogenesis in the hypophysectomized ram. *Reprod Fert Suppl* 1979;26:165-173.
39. Barth, AD, Waldner CL. Factors affecting breeding soundness classification of beef bulls in Saskatchewan. *Can Vet J* 2002;43:274-284.
40. Brinks JS, McInerney MJ, Chenowith PJ. Relationship of age of puberty in heifers to reproductive traits in young bulls. *Proc West Sec Amer Soc Anim Sci* 1978;29:28.
41. King RG, Kress DD, Anderson DD, Doornbos DE, Burfening J. Genetic parameters in Herefords for puberty in heifers and scrotal circumference in bulls. *Proc West Sec Anim Sci* 1983;34:11.
42. Lunstra DD. Testicular development and onset of puberty in beef bulls. *Beef Research Program Progress Report No. 1*. Clay Center, NE: US Meat Animal Res Cent, ARM-NC-21; 1982:26.
43. Toelle VD, Robison OW. Estimates of genetic correlations between testicular measurements and female reproductive traits in cattle. *J Anim Sci* 1985; 60:89-100.
44. Pratt SL, Spitzer JC, Webster HW, Hupp HD, Bridges WC Jr. Comparison of methods for predicting scrotal circumference to growth traits in beef bulls. *J Anim Sci* 1991;69:2711-2720.
45. Coe PH, Gibson CD. Adjusted 200-day scrotal circumference size as a predictor of 365-day scrotal circumference. *Theriogenology* 1993;40:1065-1072.
46. Makarechian M, Arthur PF. A comparison of natural service fertility of yearling and two-year-old bulls at pasture. *Theriogenology* 1993;39(3):835-845.
47. Farid A, Makarechian M, Price MA, Berg RT. Repeatability of reproductive performance of beef bulls as yearlings and two-year-olds at pasture. *Anim Reprod Sci* 1987;14:21-29.
48. Greer RC, Frank MD, Urick JJ. Yearling bull breeding performance. *Montana Agric Res* 1991;8(1):30-32.
49. Makarechian M, Farid A. The relationship between breeding soundness evaluation and fertility of beef bulls under group mating at pasture. *Theriogenology* 1985;23(6):887-898.

Upcoming Meetings

9-12 June 2004
ACVIM Forum
Minneapolis, MN
CONTACT: American College of
Veterinary Internal Medicine
Fax: 303-231-0880
Website: www.acvim.org

10-12 June 2004
WCVM/SVMA June Conference
Saskatoon, Saskatchewan
CONTACT: Anne Ruholl
Tel.: 306-966-7267

7-11 July 2004
Canadian Veterinary Medical Association
Quebec, Quebec
CONTACT: Web site: www.canadianveterinarians.net/

11-16 July 2004
23rd World Buiatrics Congress
Quebec, Quebec
CONTACT: www.wbc2004.ca

17-23 July 2004
World Sheep and Wool Congress
Quebec, Quebec
CONTACT: Web site: www.worldsheep.com/

Do you have a review article suitable for large animal practitioners? Please contact the editor by E-mail, Jon.Naylor@usask.ca for publication and remuneration details.

Change of address notices and requests for subscriptions to *Large Animal Veterinary Rounds* are to be sent by mail to P.O. Box 310, Station H, Montreal, Quebec H3G 2K8 or by fax to (514) 932-5114 or by e-mail to info@snellmedical.com. Please reference *Large Animal Veterinary Rounds* in your correspondence. Undeliverable copies are to be sent to the address above. Publications Post #40032303

This publication is made possible by an educational grant from

Schering-Plough Animal Health

© 2004 Department of Large Animal Clinical Sciences, Western College of Veterinary Medicine, which is solely responsible for the contents. The opinions expressed in this publication do not necessarily reflect those of the publisher or sponsor, but rather are those of the authoring institution based on the available scientific literature. Publisher: **SNELL Medical Communication Inc.** in cooperation with the Department of Large Animal Clinical Sciences, Western College of Veterinary Medicine. ™*Large Animal Veterinary Rounds* is a Trade Mark of SNELL Medical Communication Inc. All rights reserved. **SNELL Medical Communication Inc.** is committed to the development of superior Continuing Medical Education. The administration of any therapies discussed or referred to in *Large Animal Veterinary Rounds* should always be consistent with the recognized prescribing information in Canada.

117-031R

SNELL