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Introduction

Unlike the dairy breeder or feedlot operator, the beef breeder derives their entire income from calves born into the herd, making fertility unquestionably the most important trait to be considered in a breeding program. Economically, reproductive merit is 5 times more important to the cow-calf producer than growth performance and 10 times more important than product quality (e.g. carcass quality)[20], at least until value based marketing becomes a reality. These figures refer to the relative importance of these traits for the beef herd in total and are further magnified when discussing the bull component alone as a result of the male to female ratio at breeding. This is adequate justification to place much greater emphasis on the fertility of the beef bull.

Little selection pressure has been placed on the fertility of the world's beef bull population and as a result, variation in the reproductive potential of beef bulls is vast. Multiple sire breeding, used routinely by commercial breeders, has made it difficult to identify sub-fertile sires. Many breeders, whether purebred or commercial, have little, or no information on the reproductive status of their bulls, particularly their yearlings. Estimates of the proportion of unselected beef bulls in North America that are deficient reproductively range from 20 to 40%. Many more are barely adequate. Few breeders have bull batteries capable of impregnating all females under moderate to heavy breeding pressure in a 45-day breeding season. Achieving this is essential if a 365-day calving interval is to be maintained.

Breeding Soundness Evaluation

Four aspects of a beef bull must be evaluated to determine its reproductive potential. These include: 1) testicular and scrotal development; 2) ability to physically breed females; 3) seminal quality; and 4) bull reproductive behavior. **Each** is of **equal** importance and **all** must be adequate before normal fertility can be expected.

1. Testicular and Scrotal Development

The first activity that must be carried out in conducting an evaluation of testicular and scrotal development is a thorough palpation of scrotal contents to ensure that they are normal. First, one must make sure that the testes are not in any way adhered to the scrotum. For the testes and scrotum to function normally, the testes must be free and able to move unimpaired within the scrotum to facilitate thermoregulation. This can be checked by palpating the testes upward within the scrotum toward the abdominal wall. Adhesions between the testes and scrotum may result from physical injury, or moderate to severe scrotal frost bite. Testes should

be uniform in size. Any significant asymmetry in testicular size is a good indication of potential problems.

Testes should be uniform in consistency, both between the testes and from the dorsal to the ventral pole of each testis. Testicular consistency should be firm, but not hard. The normal testis is a resilient organ that when compressed and released will spring back to its original form. Testes should be neither mushy, nor feel as if they are soft on the surface and have a hard core. Both hard and soft spots on a testis should be noted. Soft testicular consistency is indicative of testicular degeneration and is often related to reduced sperm production, poor seminal quality and subfertility or sterility[18].

Testicular size or the amount of sperm producing tissue is estimated through the use of a scrotal circumference (SC) measurement which is highly correlated to paired testis weight[8]. Thus the SC measurement can be used to predict accurately the amount of potential sperm- producing tissue within the testes.

The technique[1] recommended for taking scrotal circumference measurements by the Society for Theriogenology (American Veterinary Society for the Study of Breeding Soundness) is as follows: First, the testes are palpated firmly into the lower part of the scrotum so they are side by side and scrotal wrinkles that might inflate the measurement are eliminated. This is of particular importance in cool weather [ambient temperature below 10ºC (50ºF)] if accurate results are to be obtained. If below 0ºC (32ºF), bulls should be evaluated in a warmer environment. Second, the thumb and fingers of one hand are placed on the sides of the scrotum cradling the testes rather than grasping either the front and back, or neck of the scrotum. The latter two techniques of stabilizing the testes-scrotum introduce error. Third, the looped scrotal tape is slipped up over the testes-scrotum and contracted around the largest circumference. Moderate tension is placed on a sliding tape with the thumb until moderate resistance is provided by the testes-scrotum. Little compression of the testes-scrotum will occur in bulls with normal testes, while in bulls having a thick, fat scrotum and/or soft testes, compression may be substantial. Firm testes having good tone and resiliency are most desirable. Fourth. the circumference is read. Once a reading has been obtained, the procedure is repeated to confirm the result.

The largest source of variation among individuals taking SC measurements is the amount of tension placed on the conventional SC measuring tape. "Moderate tension" is interpreted differently by different operators. The Coulter Scrotal Tape (Trueman Mfg., Edmonton. AB) was invented (U.S. Patent 5193287) by the author to minimize this source of error. A spring within the handle of the tape provides exactly the same amount of tension every time a SC measurement is taken, regardless of the operator. The Tape is applied in a similar fashion to conventional SC measuring tapes. First, the testes are palpated down into the bottom of the scrotum. Second, the Tape is opened and fixed in place with a button on the side of the instrument. Third, the open Tape is slid up over the scrotum to the largest circumference, the instrument is pulled slightly: toward the operator so that the Tape contacts the anterior aspect of the scrotum, while the testes- scrotum are being steadied by the operator's other hand, the button is released, and the Tape is allowed to be pulled slowly and gently toward the posterior of the scrotum by the constant tension spring. When the Tape comes to rest, the reading is taken. Caution must be

exercised not to "snap" the Tape, which will introduce error into the measurement and may cause discomfort to the bull. The Tape is again fixed with the button and slid off the bottom of the scrotum. The measurement should then be repeated.

A consistent scrotal circumference measurement technique is essential if comparisons are be made among bulls for selection purposes, or if minimum standards are applied as an eligibility criterion for bull growth performance test stations or shows.

Effects of age on SC Bull age is the factor that has the greatest effect on testicular development in young bulls from six through thirty-six months of age. Figure 1 illustrates the distribution of SC measurements by age in Aberdeen Angus bulls[10]. The most-striking aspects of this distribution are the very rapid testicular growth in young bulls (6 through 16 months of age) and the tremendous range in testes size for bulls of the same age within a breed. Paired testes weight in bulls of the same age may vary by as much as 550 g which represents a potential sperm production of over 8 billion spermatozoa per day. This pattern of testicular development is similar for all breeds.

Large variation in testicular size of bulls of the same age within a breed, coupled with the high heritability of the trait, provides considerable opportunity to improve the testicular size of bulls within a herd or breed through selection.

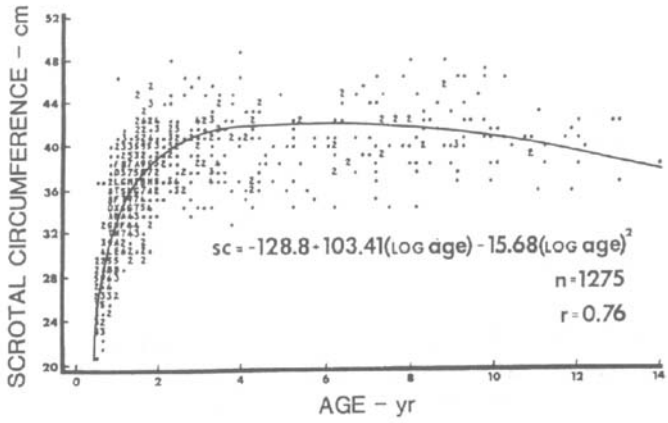

Figure 1. Distribution of SC by age in Aberdeen Angus bulls.

Age adjustment of SC Scrotal circumference measurements have been adjusted both on an age, and body weight basis. Scrotal circumference measurement is a more accurate predictor for establishing when a bull reaches puberty than either age, or body weight regardless of breed or breed cross[16]. Therefore, SC measurement in yearling beef bulls is essentially a measure of age at puberty. If the primary reason for adjusting SC measurements is to increase the accuracy of selection for age at puberty in bulls and the correlated response in age at puberty in heifers, then adjustment for age, not weight, would seem appropriate. Furthermore, body weight is not purely an environmental effect as it is influenced by genetics[3]. Published age adjustment factors for SC

measurements taken upon completion of growth performance tests as yearling range from .024 to .026 cm/d for Hereford bulls[3 13], .028 to .032 cm/d for nine[6] and twelve[17] *Bos taurus* breeds and .041 cm/d for Brangus bulls[13]. Hereford bulls fed high energy diets during growth performance testing require a higher adjustment factor of .032 cm/d[3]. All adjustment factors are in relatively close agreement.

Age of dam adjustment of SC Several reports[3 13 17] have recommended age of dam adjustment factors for SC measurements of yearling beef bulls. Although some differences occur among the studies as to the magnitude of the adjustment factor for a particular age of dam, there is general agreement that the SC measurement of bulls from two-year-old dams require the greatest upward adjustment followed by bulls from three- and four-year-old dams. Adjustment factors from one study based on twelve breeds[17] follow in Table 1. These age of dam effects may be the result of differences in calf body weight. Age of dam adjustment should be added to the SC measurement only after the SC measurement has been adjusted to 365 days of age.

Table 1. Age of dam adjustment factors for yearling beef bulls (*Bos taurus*).

Age of dam	Adjustment factor
5-yr or older	+0.0 cm
4-yr old	+0.4 cm
3-yr old	+0.8 cm
2-yr old	+1.3 cm

Recommended minimum SC Recommended minimum SC measurements[11] by age and breed are outlined in Table 2. While these minimums fall within the guidelines of the Society for Theriogenology, Cattlemen selecting herd sires should seriously consider selecting bulls having SC measurements substantially greater than the minimums listed. The objective should be to select superior bulls, not those barely adequate. Bulls having an SC measurement less than these minimums may on occasion produce an acceptable semen sample; however, such bulls have limited sperm-producing capacity and would be expected to be of unsatisfactory fertility under moderate to heavy breeding pressure.

Table 2. Minimum scrotal circumference in centimeters.

Age (months)	Simmental and Gelbvieh	Angus, Charolais and Maine Anjou	Hereford and Shorthorn	Limousin, Blonde d'Aquitaine and Salers
12-14	33	32	31	30
15-20	35	34	33	32
21-30	36	35	34	33
>30	37	36	35	34

Effect of breed on SC Breed of beef bull also influences testicular development[7 8 11 12 14]. Table 3 shows the effect of breed on SC for yearling bulls measured upon completion of a 140-day, growth-performance test and for two-year-old bulls presented for sale at spring show/sales[11]. Scrotal circumference increases from 2 to 3 cm between one and two years of age for most breeds. The difference in SC between yearlings of the extreme breeds (Simmental and Limousin) is 5.7 cm. This represents about 194 g of testicular tissue or the potential to produce an additional 2.9 billion spermatozoa per day. This example illustrates the effect breed can have on testicular size, and consequently sperm production.

Table 3. Effect of breed on scrotal circumference (cm) of beef bulls: Comparison of 1- versus 2-year-olds.

	1-year-old		2-year-old	
Breed	No. of bulls	Scrotal circumference Mean ± SE	No. of bulls	Scrotal circumference Mean ± SE
Simmental	401	36.0 ± .2	543	38.7 ± .1
Aberdeen Angus	206	33.9 ± .1	630	37.2 ± .1
Maine Anjou	311	33.7 ± .2	-	-
Charolais	607	33.1 ± .1	506	36.3 ± .1
Hereford (horned)	614	32.9 ± .1	3,769	36.1 ± .0
Shorthorn	147	32.5 ± .2	233	34.9 ± .1
Hereford (polled)	332	32.3 ± .2	2,174	35.6 ± .1
Blonde d'Aquitaine	115	30.7 ± .5	-	-
Salers	255	30.4 ± .2	-	-
Limousin	276	30.3 ± .3	80	32.1 ± .3

Effects of SC on seminal quality Studies conducted at the University of Saskatchewan[4] indicate that the probability of a beef bull having satisfactory seminal quality increase as SC measurements increase until an SC measurement of about 38.0 cm is attained. For example, of the 155 bulls having an SC measurement of 32.0 cm, only 23% were considered to be satisfactory while 88% of the 136 bulls with a 38.0 cm SC measurement were classified as satisfactory. Seminal quality improved little over 38.0 cm of SC.

Relationship between SC and bull fertility Results from a field trial conducted by the Lethbridge Research Centre[9] indicate that as SC increased in young beef bulls used for multiple-sire, natural service under range conditions, fertility also increased. Scrotal circumference made a highly significant, positive contribution to the predictive model. It should be emphasized that in this field trial bull age and SC measurement were confounded. In general, an increase in bull age is associated with an increase in SC. The precise effects of these two traits on bull fertility is difficult to separate. Although expected bull fertility increases with testicular size as measured by SC, the author expresses a note of caution here as the effect of selection of bulls with extreme SC

on their fertility and that of their progeny is unknown. For example, little benefit may be realized in the selection of two-year-old bulls with an SC measurement greater than 40.0 or 42.0 cm. This suggested upper limit to SC measurement may vary with breed.

The greatest long-term benefits of using bulls with above average testicular size may come from positive carry-over effects to their female progeny. The use of a sire with above average testicular size for his age and breed will result in female progeny that reach puberty at a younger age, cycle more regularly, and consequently have greater life time productivity. Results from a North Carolina study[19] indicate a high positive genetic correlation between bull testicular size and pregnancy rate of female progeny ® = .66). As age at puberty in females is favorably associated with subsequent reproduction[21], selection for larger SC measurements should improve the reproductive potential of the cow herd.

Scrotal shape Scrotal shape also has an influence on testicular development and function[4]. There are three basic scrotal shapes in beef bulls. These are the "normal" or "bottle-shaped" scrotum, "straight-sided" scrotum, and "wedge-shaped" scrotum. Bulls having a normal scrotum with a distinct neck (Figure 2, Bull B)[4] generally have the best testicular development and function. Testes are located in the scrotum as spermatogenesis only occurs within a narrow temperature range several degrees cooler than core body temperature. The testes move closer to, or away from, the body wall to compensate for environmental temperature in an attempt to maintain this temperature gradient. The normal scrotal configuration permits adequate temperature compensation. Often bulls with straight-sided scrotums (Figure 2, Bull A) have only moderate testicular size. The straight-sided neck of the scrotum is generally the result of fat deposits that may impair proper thermoregulation. As bulls mature and lose condition, they will often develop a more normal scrotum. Wedge-shaped scrotums (Figure 2, Bull C) are pointed towards the bottom and tend to hold the testes close to the body wall. Bulls with this scrotal configuration have undersized testes that seldom produce semen of adequate quality or quantity and should be avoided.

2. Ability to Physically Breed Females

There are numerous anatomical deficiencies and defects that can prevent or impair a bull from effectively breeding females. Good feet and legs are essential if a bull is to travel over extensive, rough terrain. Eyesight must be good to assist in the identification of estrous females. To discuss all potential anatomical abnormalities and breeding problems is not possible here. Instead, I will illustrate the dramatic effect one such defect can have on herd fertility. The defect is the spiral deviation of the penis. This defect has received almost no consideration in the evaluation of reproductive potential of North American beef bulls. However, Australian researchers[2] indicate that bulls in 60% of herds examined were affected, and that 1% of horned bulls and 16% of polled bulls had the defect. There is no reason to believe the prevalence of the spiral penile deviation would be any less in North America. Spiral penile deviations are most often found in bulls 3 to 6 years of age. Five bulls having an incidence of the spiral penile deviation of 100, 100, 80, 50, and 0 % of the time had respective pregnancy rates of 3, 3, 33, 43 and 87 %. The spiral penile deviation can not be diagnosed at the time of electroejaculation. In fact, electroejaculation can induce a similar penile configuration that may not occur at all during

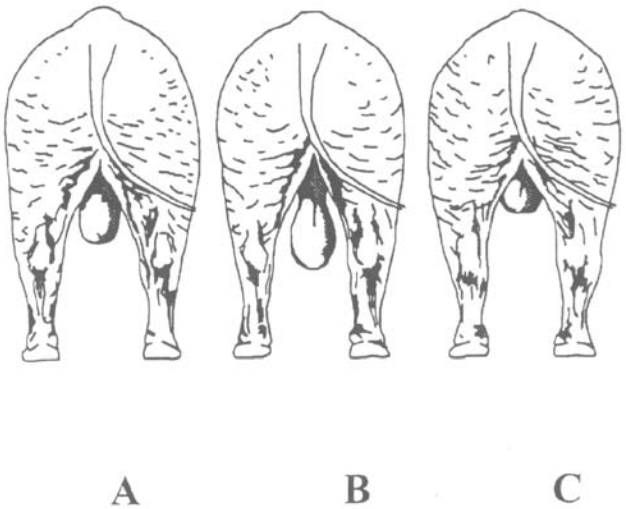

Figure 2. Three scrotal shapes commonly seen in beef bulls are the straight-sided scrotum (A), the normal scrotum (B), and the wedge-shaped scrotum (C). Scrotal shapes A and C are the least desirable (adapted from Cates, 1975).

natural service. Cattlemen must watch the breeding activity of their bulls to ensure the absence of this defect. Also, the defect tends to be moderately heritable. This is a good example of how the reproductive potential of bulls must be examined to improve the probability of using bulls of average to superior fertility.

3. Seminal Quality

Results from semen testing young beef bulls (11 to 13 months of age) should be interpreted with caution. Seminal quality in young bulls has been demonstrated to improve, often dramatically, for up to 16 weeks following puberty[15]. Puberty will occur at different ages and body weights depending on the breed, management, and genotype of the individual bull. A scrotal circumference measurement of 26. 1 cm at puberty is relatively constant among breeds differing widely in age and weight at puberty[16]. Cattlemen should be advised to semen test their young bulls at 14 to 16 months of age to avoid the potential early culling of a bull that may have adequate seminal quality two months later.

Under field conditions, the seminal sample is usually obtained by electro-ejaculation. Prior to electroejaculation, a rectal examination of the bull's internal organs should be performed. This also removes faecal material from the rectum ensuring proper contact for the electro ejaculator probe. A common problem in young beef bulls that can be diagnosed at this time is seminal vesiculitis caused by an infection in one or both seminal vesicles. Vesiculitis results in the seminal vesicles becoming enlarged, sometimes two to three times their normal size, and quite turgid to the touch. In severe cases, the palpation of the infected seminal vesicles may be quite painful to the bull. Some controversy exists as to whether treatment of seminal vesiculitis is effective or

whether the condition will correct itself in time. Generally, bulls with severe seminal vesiculitis can not be recommended for use. Seminal vesiculitis can also be detected by the presence of white blood cells in the ejaculate.

The two most important factors to be examined in the semen are the proportion of spermatozoa that are progressively motile and the morphology of the spermatozoa. In the field trial referred to earlier[9], bull fertility decreased significantly as the number of spermatozoa with primary defects increased. In this trial, neither the number of secondary defects, nor the proportion of normal acrosomes contributed significantly to the variance in bull fertility. A third factor, the concentration of spermatozoa in an ejaculate is difficult to assess when the semen sample is collected by electro-ejaculation.

Positive results from a seminal evaluation, even in yearling bulls indicate a moderate to high probability of acceptable fertility, while negative results are **not conclusive**, particularly if the bulls involved are young or sexually rested. Subsequent evaluations of bulls with poor seminal quality should be carried out at 3- to 4-week intervals. If the results do not improve, the breeder can be quite confident that the bull is infertile and should be culled. Seminal evaluations need to be conducted as close to the breeding season as possible. However, the breeder must allow enough time to retest bulls if necessary. All bulls should be tested before every breeding season as injuries, frost bite, or other problems may have reduced the bull's seminal quality since the previous evaluation.

4. Bull Reproductive Behavior

In the author's opinion, this aspect of bull evaluation is in its infancy. The reader is referred to[5] as a review source. The single most important aspect of reproductive behavior of beef bulls that must be impressed upon cattlemen is that they must carefully monitor the breeding activity of their bulls. The fact that a bull is mounting estrous females does not necessarily mean that they are being bred. Cattlemen must recognize the differences between mounting, copulation and ejaculation. Many do not know the difference, nor do they pay adequate attention. Only careful observation will allow defects such as spiral penile deviations to be detected.

Use of a comprehensive evaluation and selection program for reproductive potential in young beef bulls, coupled with optimum management will increase the probability that highly fertile sires will be available for natural service in a beef breeding program.

Strive for fertility first!

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