CHAPTER 7

RELATIONSHIP BETWEEN GROWTH PARAMETERS, SCROTAL CIRCUMFERENCE AND SHEATH AREA IN TROPICALLY ADAPTED BEEF BULLS

7.1 ABSTRACT

The relationship between growth parameters such as initial weight at the start of the trial, average daily gain for the trial period (ADG), average daily gain per day of age (ADA), feed conversion ratio (FCR), final weight at the end of the trial, scrotal circumference (SC) and age and sheath area in Santa Gertrudis bulls were examined. To investigate the relationship between growth parameters and scrotal circumference, growth test data of 97 on-station performance tested Santa Gertrudis bulls were used while growth results of 55 Santa Gertrudis bulls tested under semi-intensive conditions were used to investigate the relationship of sheath area with growth performance. Bulls were divided into two groups according to their average sheath area (470 cm^2). 28 Bulls were assigned to the small sheath group (SSA) below 470 cm^2 group while 27 bulls were assigned to the large sheath group (LSA) above 470 cm^2. The LSA group possessed a 15% (66 kg; $p < 0.05$) heavier final weight than that of the SSA group. The LSA group had a 64% (241 cm^2; $p < 0.05$) larger sheath area (378 ± 60 cm^2 vs 619 ± 161 cm^2) than the SSA group. A significant phenotypic correlation between ADG ($r = 0.31$, $p < 0.05$) and sheath area was found. The correlations between sheath area and initial weight ($r = 0.42$, $p < 0.001$) and between sheath area and final weight ($r = 0.45$, $p < 0.001$) were also highly significant. A highly significant

correlation ($p < 0.001$) was observed between initial weight and SC and between final weight and SC, while significant correlations ($p < 0.05$) were also observed between SC and age, and between SC and ADA for bulls tested intensively on station.

It appears that SC and faster growth rate are compatible in young bulls. In addition, yearling bulls with acceptable sheath areas can be selected without necessarily sacrificing growth performance.

7.2 INTRODUCTION

Natural mating accounts for more than 90% of the pregnancies in the beef cattle industry in South Africa (Hoogenboezem, 1995), 95% in beef cattle operations in the USA (Healy *et al.,* 1993, Parkinson, 2004) and up to 85% of the pregnancies in beef cattle in the tropical regions of the world (Galina and Arthur, 1991, Torres and Henry, 2005). MacGregor (1997) reviewed the natural calving percentage in beef herds in South Africa and found no improvement in the national calving percentage over the past 30 years. The calving percentage still remains less than 60% despite the change from subjective selection of cattle to objective selection based on economically important traits. Poor reproductive performance is the major reason that cows are removed / culled from the herd (Greer *et al.,* 1980, Freeden *et al.,* 1987, El-Said *et al.,* 2001, Formigoni and Trevisi, 2003). Brinks (1994) and De Jarnette *et al.* (2004) stated that it could be quite possible that although females are culled for low expressed reproduction, sires with only average reproductive potential are subsequently used resulting in female offspring that again need to be culled for low reproductive performance. It seems that continued culling of poor reproducers (cows) will improve the reproductive potential of a herd only marginally if sires with an average reproductive potential are continuously used. Many factors, including scrotal circumference as an indicator of testis size, are highly correlated with sperm production and semen quality in growing bulls and (Coulter and Foote, 1979, Brinks, 1989, Bellows and Staigmiller, 1994, Vásquez *et al.,* 2003, Parkinson 2004) forms a significant component of the breeding soundness examination (BSE) recommended by the society of Theriogenology (Ball *et al*., 1986). The BSE is widely used for both yearling and older bulls and especially for yearling bulls at the conclusion of performance tests (Brinks, 1994, Vásquez *et al.,* 2003, Parkinson 2004).

Swanepoel and Heyns, (1986), Fitzpatrick *et al*. (2002) and Field and Taylor, (2003) are of the opinion that large variation in the pregnancy rate of beef cattle exists owing to differences in the ability of bulls to bring about conception in cows. Small scrotal circumference (Eler *et al.,* 2004) and large pendulous sheaths (McGowan *et al.,* 2002) are two of the main factors causing this variation (Swanepoel and Hoogenboezem, 1993). Although some consideration has been placed on scrotal circumference in the male as a means of improving male fertility in recent years, greater selection pressure is still placed on growth rate and feed efficiency than on scrotal circumference and sheath development. This occurs despite Neely *et al.* (1982), Knights *et al.* (1984), Bourdon and Brinks (1986) Lunstra *et al.* (1988) and Smith *et al.* (1989) indicating that SC is favourably related to growth from birth to yearling ages, but lowly related to birth weight. Studies (Smith *et al.,* 1981, Gipson *et al.,* 1985, Bourdon and Brinks 1986) have indicated that bulls with smaller SC have lower fertility than bulls with larger SC. Bulls with larger SC produce more sperm (Almquist and Amann 1961, Parkinson 2004) and higher quality semen (Fields *et al.,* 1982, Parkinson 2004). The objective of this study was to examine the relationship between growth parameters and scrotal circumference in Santa Gertrudis bulls. In addition, a second objective was to investigate the relationship between sheath area and growth traits in Santa Gertrudis bulls.

7.3 MATERIAL AND METHODS

To investigate the relationships between growth parameters and scrotal circumference, growth test data of 97 Santa Gertrudis bulls tested under phase C conditions (an 84 day intensive post-weaning growth test following a 28 day adaptation period for stud bulls at a centralised testing station, coordinated by the National Beef Cattle performance and progeny testing scheme) were used. The South African Santa Gertrudis Beef Cattle Breeders Society, in Bloemfontein, South Africa, supplied growth performance information.

Bulls received a diet consisting of 11 MJ/kg DM minimum (min) and 74.8% digestible energy), an average of 13.8% crude protein (135 g/kg – 150 g/kg), non-degradable protein (45 g/kg min), Urea (7 g/kg maximum (max)), fibre (125 g/kg), roughage (200 g/kg), fat (30 g/kg), calcium (9 g/kg), phosphorous (4 g/kg), sulphur (2.2 g/kg), magnesium (2.5 g/kg), manganese (40 mg/kg), zinc (25 mg/kg), iodine (2 mg/kg), selenium (0.15 mg/kg), iron (50 mg/kg), copper (15 mg/kg) and cobalt (0.5 mg/kg). Feed was supplied *ad libutum* in a pellet form to limit wastage. Bulls were housed in an open-end barn and fitted with transponders for calan gates, in order to facilitate individual feeding. Growth parameters measured were initial weight (at the start of the intensive feeding trial) average daily gain (ADG) over the 84 days intensive feeding period, average daily gain per day of age (ADA). Feed conversion ratio (FCR) took into account the amount of feed consumed to produce a change of 1 kg in weight and was expressed as a ratio. Final weight at the end of the trial, age and scrotal circumference (SC) were also studied. SC was measured by palpating the testis to the bottom of the scrotum and measuring (with a tape measure) the scrotum at its largest circumference. This was done at the beginning of the trial, followed by a two weekly measurement and the last measurement taken on the day the trial period ended.

To investigate the relationship of sheath area with growth performance, growth results of 55 Santa Gertrudis bulls, tested under phase D conditions (a semi-intensive, on-farm post weaning growth test for stud and commercial bulls, coordinated by the National Beef Cattle Performance and progeny testing scheme) were used. Bulls received a diet having an average energy content of 8.8 MJ ME/kg, an average of 15.4% crude protein (150 g/kg min), protein excluding non-protein nitrogen (57.4%), Urea (30 g/kg max), fibre (100 g/kg max), moisture (160 g/kg max), fat (2.25 g/kg min), calcium (20 g/kg max), phosphorous (6 g/kg min), sulphur (6.5 g/kg), magnesium (6 g/kg), manganese (100 mg/kg), zinc (100 mg/kg), iodine (1.25 mg/kg), selenium

(0.25 mg/kg), iron (150 mg/kg), copper (30 mg/kg) and cobalt (0.3 mg/kg), in a lick form and group fed. The concentrated lick constituted ± 50% of the animal's daily intake. The remaining 50% of the daily requirements were supplied in the form of hay bales containing 5.2% crude protein and 14.5% digestible energy. The South African Santa Gertrudis Cattle Breeders Society in Bloemfontein, South Africa made growth performance data available. Sheath area was calculated by photographing each animal from a standard distance in front of a grid of known measurements. This technique has previously been used by Franke and Burns (1985) in Brahman bulls.

Bulls were divided into two groups according to their average sheath area. The average sheath area was 470 cm^2. There were 28 bulls below the average, with a mean of 378 ± 69 cm^2 constituting the small sheath group, and 27 bulls above the average, with a mean of 619 ± 161 cm^2 constituting the large sheath group.

Pearson's rho correlations were determined by Standard GLM Procedure of Statistical Analysis System (SAS, 1995).

7.4 RESULTS AND DISCUSSION

The correlation coefficients of growth parameters with scrotal circumference are presented in Table 7.1.

Table 7.1 : Pearson's correlation coefficients between scrotal circumference and growth parameters of 97 Santa Gertrudis bulls.

Growth parameter	Scrotal circumference
Initial weight (kg)	0.32[a]
Average daily gain (g)	0.12
Average daily gain per day of age (g)	0.15[a]
Feed conversion ratio	0.05
Final weight (kg)	0.37[a]
Age (days)	0.13[a]

Correlations with superscripts [a] are at the $p < 0.05$ level of significance.

From the results presented in Table 7.1, it is evident that a highly significant correlation ($p < 0.001$) exists between initial weight and scrotal circumference and between final weight and scrotal circumference. These results agree with those of Neely *et al.* (1982), Bourdon and Brinks (1986), Hoogenboezem (1995), McGowan *et al*. (2002) and Crews and Porteous (2003) and indicate that the genetic and phenotypic correlations between SC and measures of growth are generally favourable. Significant correlations ($p < 0.05$) exist between SC and age and between SC and average daily gain per day of age (Table 7.1). Average daily gain per day of age is a function of age. In addition, body weight and age are positively correlated in young bulls, which could explain the significant correlation found between SC and age and between SC and ADA. Makarechian *et al.* (1984) and Barth and Waldner, (2002) established that factors such as breed, age and season and body weight influence SC. Although the correlation between SC and average daily gain, and that of feed conversion ratio are non-significant, they are favourable and it appears that there is a trend towards a higher correlation between final weight and SC than that recorded between initial weight and SC. A similar tendency was observed by Knights *et al.* (1984) in yearling Angus bulls. Crews and Porteous (2003) reported a high correlation between pre-weaning growth and testicular development in beef bulls. Their results indicate that the chances of selecting beef bulls with increase in small testes for breeding purposes is generally low, when pre-weaning gain was considered in the selection program. This may further explain the significant correlation between SC and average daily gain per day of age, because ADA includes pre-weaning gain. It is evident that the pre-weaning stage is a critical period for testicular development. Bulls with inferior testicular development at a young age showed an increase in SC with both age and body weight, but those bulls with superior development at a relatively young age maintained that advantage throughout life (Hoogenboezem and Swanepoel, 1995, Barth and Ominski, 2000). Therefore, the probability of finding bulls with smaller than average testis among bulls selected for weaning weight would be less than in bulls selected for growth rate in a feedlot test. This observation was also confirmed in the study of Swanepoel and Heyns (1986) with Simmentaler bulls. This is further supported by the results presented by Ellis *et al.* (2005), indicating that with loss of body condition there is a subsequent loss in SC in young bulls. Lunstra *et al.* (1988), Smith *et al.* (1989), Brinks (1994) and Crews and Porteous (2003) reported that the genetic correlation between SC and birth weight is relatively low, whereas the genetic correlation between SC and yearling weight is relatively high. This suggests that larger SC and faster growth rate are compatible in young bulls. Therefore, selection for increased

SC should result in increased growth from birth to yearling ages while keeping birth weights relatively constant.

7.5 GROWTH PARAMETERS AND SHEATH AREA

The least squares means for traits measured during the semi-intensive phase D test are presented in Table 7.2 and the correlations between sheath area and growth parameters are presented in Table 7.3.

Table 7.2 : Least squares means and standard errors (±SE) of different traits measured at the end of a phase D test for bulls, below (small sheath area) and above (large sheath area) the average sheath area.

Trait	Below 470 cm^2 (SSA)	Above 470 cm^2 (LSA)
Number of bulls (n)	28	27
Final weight (kg)	437 ± 61[a]	503 ± 63[b]
Average daily gain (g)	1395 ± 203[a]	1513 ± 163[b]
Sheath area (cm^2)	378 ± 69[a]	619 ± 161[b]

Rows with different superscripts [a,b] differ significantly at the $p< 0.05$ level

Table 7.3 : Pearson's correlation coefficient of sheath area with growth parameters.

Growth parameter	Sheath area
Initial weight (kg)	0.42[a]
Final weight (kg)	0.45[a]
Average daily gain (g)	0.31[a]

Correlations with superscripts [a] are at the $p < 0.05$ level of significance

The results presented in Table 7.2, show a significant increase in average daily gain of 118 g (1395 ± 203 vs 1513 ± 163g), which results in a 9%

advantage in favour of the large sheath group. The large sheath group also had a 66 kg (437 ± 61 vs 503 ± 63 kg) heavier final weight, which was 15% more than that of the small sheath group. However, the large sheath group had a 64% (241 cm^2) larger sheath area (378 ± 60 vs 619 ± 161cm^2) than the small sheath group. Results in Table 7.3 show that sheath area is significantly phenotypically correlated to average daily gain ($r = 0.31$, $p < 0.05$) on test. However, this correlation is of a low order. Sheath area and initial weight ($r = 0.42$, $p < 0.001$) and sheath area and final weight ($r = 0.45$, $p < 0.001$) were highly significantly phenotypically correlated.

From the results obtained in this study, it is evident that post weaning growth did not account for a significant amount of variation in sheath area. This is also substantiated by Franke and Burns (1985) in their study of growth with Brahman calves and Kriese *et al.* (1991) in young Brangus bulls. McMurry and Turner (1990) reported a correlation ($r = 0.26$) between weaning weight and sheath area. The results presented in Table 7.3 together with the results of Franke and Burns (1985), McMurry and Turner (1990) and Kriese *et al.* (1991) suggest that selection could be effective in reducing sheath area, but it could be antagonistic to pre and post weaning growth. The relatively low order of the correlation ($r = 0.31$) for post weaning growth rate and sheath area, indicate that continued emphasis on improved growth could be maintained with careful attention to culling bulls with large sheaths. Similar results were reported by Franke and Burns (1985), for the relationship of sheath area with pre weaning growth in Brahman calves. It is evident that selection could be practised for increased growth traits along with emphasis on smaller sheath area which is supported by Kriese *et al.* (1991).

7.6 CONCLUSION

Scrotal circumference and faster growth rate is compatible in young bulls. Therefore, selection for increased SC should result in increased growth from birth to yearling ages while keeping birth weights relatively constant. Furthermore, yearling beef bulls with acceptable sheath areas can be selected without necessarily sacrificing growth performance.

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CHAPTER 8

ASSOCIATIONS AMONG GROWTH AND QUANTITATIVE TESTICULAR TRAITS OF TROPICALLY ADAPTED YEARLING BULLS FED DIFFERENT DIETARY ENERGY LEVELS.

8.1 ABSTRACT

The effect of high energy (HE), medium energy (ME) and low energy (LE) diets fed to young Bonsmara bulls post-weaning on scrotal circumference (SC), average daily gain over a 84 day performance test trial period (ADG), average daily gain per day of age (ADA), body condition score (BCS), testicular histology and seminal traits were examined. Bulls fed the HE diet were significantly heavier and had a greater ADA, with the HE bulls (999.1 ± 7.13 g) out performing the ME (804.1 ± 12.61 g) and LE (713.2 ± 12.95 g) bulls in growth rate over the duration of the experimental period. Diet influenced ($p < 0.001$) BCS with the HE bulls (3.9 ± 0.05) having more body fat compared to the ME (3.3 ± 0.06) and LE (3.0 ± 0.08) bulls with the same effect ($p < 0.001$) observed in the carcass dressing percentage of the bulls fed different levels of energy. SC did not differ significantly between HE, ME and LE fed bulls. Seminal traits, such as semen concentration were significantly ($p < 0.001$) lower in bulls fed the HE diet (1.3 ± 0.134) compared to those fed the ME diet (2.4 ± 0.18) and LE diet (2.6 ± 0.16). Similarly, linear movement of sperm was also affected by diet and movement was slower ($p < 0.05$) in bulls fed the HE diet (1.7 ± 0.30) compared to bulls fed the ME diet (2.2 ± 0.31) and LE diet (3.1 ± 0.23). The percentage total major ($p < 0.001$) and total minor ($p < 0.05$) sperm defects were also greater in the HE fed bulls (27.1 ± 6.82 and

7.4 ± 0.91 compared to 9.7 ± 1.45 and 5.5 ± 0.87 for the ME fed bulls and 5.4 ± 1.26 and 3.9 ± 6.58 for the LE fed bulls). Dietary energy level significantly ($p < 0.001$) influenced the percentage inactive seminiferous tubuli, with bulls fed the HE diet having 35% more seminiferous tubules classified as inactive compared to those bulls fed ME and LE diets. Scrotal fat deposits were higher ($p < 0.05$) in bulls fed the HE diet (243.4 ± 21.59 g) compared to those fed the ME (110.0 ± 12.1 g) and LE (88.4 ± 9.65 g) diets. Correlation coefficients between SC and growth traits were generally favourable for the different dietary treatments. Correlations between live weight and SC were 0.51, 0.45 and 0.52 ($p < 0.05$) for the HE, ME and LE groups respectively. A trend was recorded toward a negative association between BCS and progressive sperm motility in bulls fed the HE diet ($r = -0.54$, $p < 0.05$). The percentage major seminal defects was negatively correlated with live weight in bulls fed the LE diet ($r = -0.46$, $p = 0.008$) and ME diet ($r = -0.40$, $p = 0.08$), while this characteristic was negatively correlated with mass movement of sperm ($r = -0.63$; $p < 0.05$) and percentage live sperm ($r = -0.60$; $p < 0.05$) in HE fed bulls. Feeding HE diets to young bulls reduced their reproductive potential.

8.2 INTRODUCTION

Reproductive performance has greater impact on beef economic returns than does either growth rate or product quality (Trenkle and Wilham, 1977). In most cow-calf operations, females still conceive via the natural breeding bull (Godfrey and Lunstra 1989, Chacon *et al*., 2002, Parkinson 2004, Torres-Junior and Henry 2005) as only 5% of semen sales in South Africa are for beef bulls. Although Galina and Arthur (1989) reported that 85% of Zebu breeding in the tropics occurs by natural mating, published research on the reproductive characteristics of bulls in the tropics is scarce. According to Carson and Wenzel (1997) and Holroyd *et al*. (2004) almost 40% of bulls tested in their study had reproductive problems, but Chenoweth (1981) and results presented by Kennedy *et al.* (2002) on 3648 performance tested bulls, showed that approximately 30% of bulls used for breeding have reproductive problems. It also appears that the variation in the reproductive potential of beef bulls is vast (Coulter, 1994, Fitzpatrick et al., 2002). Many cattle breeders in South Africa have little or no information on the reproductive status of their bulls, particularly their young bulls. In many cases, bulls are not assessed prior to sale or use (Godfrey and Lunstra, 1989). Reproductive efficiency of both bulls and females contributes to the expressed reproductive performance of the cow herd (Brinks, 1994, Du Plessis *et al*., 2005) and the use of sub-fertile bulls could decrease the fertility of the herd.

Scrotal Circumference (SC) is a trait frequently used as a predictor of bull fertility (Brito *et al*., 2004). Studies reviewed by Coulter and Foote (1979), Brinks (1989), Kastelic *et al.* (2001) and Parkinson (2004) suggest that scrotal circumference measurements in bulls are of value for the prediction of potential sperm production and breeding soundness. Seminal evaluations are an alternative and complementary method of estimating reproductive capacity of bulls. In addition, scrotal circumference has a moderate to high heritability (Lôbo *et al*., 2000, Burrow 2001, Maiwashe *et al*., 2002, Martinez-Velazques *et al*., 2003, Silva *et al*., 2006). SC provides a good indication of puberty in young bulls and moderate, but favourable correlations have been found between SC and semen quality (Chacon *et al.,* 1999, Coe 1999). This is important since heritability estimates of semen traits are generally low (Pearson *et al.,* 1984, Smith *et al.,* 1989). High genetic correlations were found between SC in the bull and age at puberty in half-sibling heifers (Brinks *et al.,* 1978, King *et al.,* 1983, Toelle and Robinson, 1985, Parkinson 2004). SC is also an important measurement that makes up 40% of the total in the Breeding Soundness Evaluation endorsed, by the Society for Theriogenology, (Ball *et al.,* 1983, Chenoweth 1993). However, SC is a growth trait that may be affected by genetic, environmental or individual bull differences (Randel, 1994). Nutrition is an environmental effect that may adversely affect seminal quality and this effect is difficult to quantify. Abdel-Raouf (1960) reported that diets adequate in protein, vitamins, minerals and energy appear to hasten the onset of puberty in beef bulls. Coulter (1994), however cautions that the feeding of high-energy diets to post-pubertal beef bulls may be of no benefit to reproductive capability including seminal quality and may in fact reduce their reproductive potential. Chenoweth *et al.* (2002) also sited some studies that demonstrate the adverse nutritional effects on bull libido.

The aim of this study was to determine whether SC is an accurate predictor of semen quality (reproductive potential) and productive capacity of young tropically adapted beef bulls fed different levels of energy post-weaning. In addition the effect of high-energy diets on the reproductive and productive potential of young bulls was researched.

8.3 MATERIALS AND METHODS

Purebred Bonsmara bulls (n = 50), averaging 380 days of age were obtained from Bonsmara cattle breeders in the Bloemfontein area of South Africa. Bulls were randomly allocated to the 3 dietary treatments, varying in energy level and level of intake.

Only bulls meeting preconditioning requirements and physical inspection as prescribed by the South African Beef Cattle Performance Testing Scheme were included in the analysis of the intensive and semi-intensive feeding programs.

Eighteen bulls (n = 18) were performance tested and fed intensively on a high-energy (HE) diet for 84 days, following a 28-day adaptation period before commencing with the data collection. The high energy ration was offered *ad libitum* in a pellet form and contained 11 MJME/kg DM minimum [min] and 74.8% digestible energy, 13.8% crude protein (135 g/kg – 150 g/kg), non-degradable protein (45 g/kg min), Urea (7 g/kg maximum [max]), fibre (125 g/kg), roughage (200 g/kg), fat (30 g/kg), calcium (9 g/kg), phosphorous (4 g/kg), sulphur (2.2 g/kg), magnesium (2.5 g/kg), manganese (40 mg/kg), zinc (25 mg/kg), iodine (2 mg/kg), selenium (0.15 mg/kg), iron (50 mg/kg), copper (15 mg/kg) and cobalt (0.5 mg/kg). The experimental bulls were penned in an open front barn fitted with a feed station (milkrite) and transponders in order to measure the feed intake and feed conversion efficiency of each bull.

The bulls (n = 17) fed on the medium energy diet (ME) were subjected to a 28-day adaptation period and a performance-testing period of 84 days in which growth performance was measured. Bulls in the semi intensive fed (ME) programme were group fed and received a concentrate approximately 50% of the animal's daily intake. The remaining 50% of the animal's daily intake was offered in the form of roughage (hay bales). The concentrate contained a similar composition to the HE ration except for a 16.5% crude protein, while the hay contained a 3.2% crude protein and 7.5 MJ/kg DM energy.

Bulls (n = 15) on the low energy (LE) diet were grazed on pasture with a 5.4% crude protein and 8 MJME/kg DM energy content. Light supplementation in the form of a lick at 0.5% of body weight occurred, the supplementation intake being limited by means of NaCl.

Performance data recorded were initial weights before commencing with the feeding and growth trials, end weights measured at the end of the feeding trials, age of the bulls at the start of the study, average daily gain (ADG) during the test period, average daily gain per day of age (ADA), body condition score (BCS), carcass dressing percentage (CDP) and scrotal circumference (SC). BCS was recorded at the end of the 84th day trail period and assessed using the 1 – 5 scoring system as described by Taylor and Swanepoel (1999) where 1 is considered emaciated and 5 is extremely fat. Weighing of bulls and recording of other measurements occurred at two-week intervals.

At the end of the test period scrotal circumference (SC) was measured at the widest portion of the testes by palpating the testicles to the bottom of the scrotal sac and measuring the scrotum circumference with a scrotal tape. The bulls were considered as having reached puberty in all the groups, although puberty is often defined as the first time a bull produces an ejaculate with at least 50 x 10^6 spermatozoa /ml with at least 10% progressively motile spermatozoa. Bulls have also been considered as having reached puberty at a SC measurement of 26.1 ± 0.2cm (Coulter *et al*., 1986), and this is relatively constant among breeds differing widely in age and weight at puberty (Lunstra *et al*., 1978).

At the end of the 84-day performance test, all bulls were subjected to a fertility test. Semen was collected by means of electro-ejaculation as it was found to be comparable to semen collected with an artificial vagina (Austin *et al.,* 1961b, Coulter *et al.,* 1997). Under the experimental conditions and given the possible complications of over fat bulls with lower libido (Coulter, 1994), the electro-ejaculation method was the preferred method. It was possible that the limited handling experienced by the bulls run on natural pasture could have affected semen quality. However, they did have the benefit of increased exercise compared to stall fed bulls. The Breeding Soundness examination (BSE) endorsed by the society of Theriogenology (Ball *et al.,* 1983, Chenoweth *et al.,* 1993) served as the guideline for the evaluation of spermatozoa. Total volume of the ejaculate was measured using a calibrated test tube. Mass movement was evaluated on a 1 to 5 scale (0 = no movement; 1 = individual spermatozoa movement; 2 = movement; 3 = slight wave movement; 4 = wave movement; 5 = rapid wave movement) using a phase contrast microscope at 40 x magnification. Sperm morphology was also evaluated by means of the phase contrast microscope, with two direct counts of 100 spermatozoa, fixed on a glass slide and stained with eosin and nigrosin. The semen abnormalities were then grouped into percentage major and minor defects. Major defects included, underdeveloped heads, double forms, acrosome defects, decapitated heads, diadem, pear-shaped heads, narrow at base of head, abnormal contour, small heads, free path heads, corkscrew defect, mid-piece defects, proximal droplets, pseudo droplet and dag defect, while minor defects included, narrow heads, small normal heads, giant and short broad heads, free normal heads, detached acrosome membrane, abaxial implantation, distal droplet, simple bent tail and terminal coiled tails. Objective semen concentration was measured by microscopic counting on a haemocytometer (Pruitt and Corah, 1985) using a 100:1 dilution of semen (100 ml Sodium citrate to 1 ml semen), while subjective semen concentration was divided into 3 categories to simplify the statistical analysis (1 = watery; 2 = milky; 3 = creamy).

Once the fertility test had been completed the bulls were slaughtered and the carcass dressing percentage determined as a measure of degree of fatness. After retrieval of the testes at slaughter, six parenchyma samples per bull were taken from the dorsal, middle and ventral portions of each testis. These specimens were fixed in Bouin's solution for 24 to 48 hours, trimmed, loaded in cassettes and stored in 70% alcohol until processing. Subsequently the tissues were handled by standard tissue preparation techniques to preserve cell and tissue integrity. Tissue sections of 5 µm thick were stained with haematoxylin and eosin and graded by beginning 5 mm to the right and 5 mm down from the upper left hand corner of the tissue section as stated in the procedure used by Thompson *et al.* (1992). The degree of germinal epithelial loss was determined by the technique reported by Madrid *et al.* (1988). Tubules were graded for depletion of spermatocytes and classified as either active (spermatocytes and spermatids present) or inactive (no spermatocytes and spermatids present) as described by Thompson *et al*. (1994). Although the tubules classified as inactive could have had spermatogonia, it was concluded they did not produce spermatocytes or that the spermatocytes were lost because of damage prior to procurement of testicular parenchyma. With testicular degeneration, the first histological noticeable effect is usually on the primary spermatocytes, regardless of the testicular insult (Coulter, 1994). Finally the amount of fat surrounding the testis in the scrotum was dissected and weighed.

Data were analysed as a one-way analysis of variance with diet as the main effect using PROC GLM (SAS, 1995) to determine differences relating to the dependent variables. Tukey's HSD was used to test for differences between diet means. While normality within diet, homogeneity of variances and distribution of the error terms were determined by ANOVA. Where the homogeneity of variance assumptions were not met using Levene's test, Welch's ANOVA was used. In cases where severe deviations from normality occurred, data were transformed to normalise distributions. For variables where these deviations persisted, a median-score non-parametric test was applied to determine statistical significance between dietary treatments. Correlations between the dependent variables were determined by employing the Pearson's rho correlation.

8.4 RESULTS AND DISCUSSION

The effect of high, medium and low energy diets on growth characteristics, body condition scoring and dressing percentage are presented in Table 8.1. Although not significant ($p = 0.073$) bulls fed the high-energy diet (HE) were younger (362.7 ± 3.98) than the bulls fed the medium-energy (ME) diet (373.4 ± 2.21) and low-energy (LE) diets (367.2 ± 2.25). Although bulls fed the HE diet were approximately 8 days younger than the ME and LE fed bulls, the former were heavier ($p < 0.001$) at the end of the testing period. HE fed bulls weighed 56.3 kg and 78.3 kg more than bulls in the ME and LE groups respectively. As would be expected, bulls fed the HE diet, despite being younger and having heavier body weights, at the end of the testing period, gained more weight per day ($p < 0.001$) during the testing period, 1685.1 ± 41.49 g compared to 896.7 ± 47.04 g for the ME and 696.7 ± 37.35 g for the LE bulls. Corbet *et al.* (2006) reported a mean ADG of 1.08 kg/day for Bonsmara bulls, growth tested intensively and semi-intensively. Average daily gain for day of age followed a similar trend with the HE bulls (999.1 ± 7.13 g) out performing ($p < 0.001$) the ME (804.1 ± 12.61 g) and LE (713.2 ± 12.95 g) bulls. Body condition score was influenced by diet, with the HE bulls having significantly ($p < 0.001$) more body fat compared to both the ME and LE bulls. In turn the ME fed bulls deposited more body fat ($p < 0.001$) compared to the

LE fed bulls (Table 8.1). The advantage in BCS of the HE bulls was to some extent reflected in the dressing percentage obtained at slaughter (Table 8.1). Coulter and Kozub (1984) found similar results and reported higher body weights, average daily gain and back fat thickness in bulls fed high energy diets compared to bulls fed a medium energy diet. Coulter and Kozub (1989), Coulter *et al.* (1987), Coulter and Bailey (1988), Coulter (1994) and Barth (1997) reported a negative relationship between back fat thickness and bull fertility, while Greenough (1986) speculated that feeding high-energy diets to young beef bulls may also have a detrimental effect on hooves and legs, which may in turn have a negative influence on bull fertility.

Table 8.1 : The effect of high, medium and low energy diets on age and on live weight at the end of the trial, on carcass dressing percentage (CDP), body condition score (BCS), average daily gain (ADG) for the trial period and average daily gain for day of age (ADA)

Trait	**n**	**High**	**n**	**Medium**	**n**	**Low**
Age (days)	18	362.7 ± 3.98^{a}	17	373.4 ± 2.21^{a}	15	367.2 ± 2.56^{a}
Live weight (kg)	18	378.3 ± 8.06^{a}	17	322.6 ± 6.52^{b}	15	300.0 ± 6.30^{b}
CDP (%)	18	55.1 ± 0.59^{a}	17	53.3 ± 0.51^{ab}	15	52.1 ± 0.81^{b}
BCS (1 – 5)	18	3.9 ± 0.05^{a}	17	3.3 ± 0.06^{b}	15	3.0 ± 0.08^{c}
ADG (g)	18	1685.1 ± 41.49^{a}	17	898.7 ± 47.04^{b}	15	696.7 ± 37.35^{b}
ADA (g)	18	999.1 ± 17.13^{a}	17	804.1 ± 12.61^{b}	15	713.2 ± 12.95^{b}

Rows with different ^{a,b,c} superscripts differ at the $p< 0.001$ level of significance

Scrotal circumference (SC) is highly correlated with reproductive traits such as testicular weight (Hahn *et al.,* 1969, Coulter and Foote, 1976, Coulter and Keller, 1982, Arteaga et al., 2001) and sperm production (Hahn *et al.,* 1969, Gipson *et al*., 1985, Arteaga et al., 2001, Parkinson 2004). Measurements for scrotal circumference are represented in Table 8.2, and are similar to the mean SC of 33.9 cm reported by Corbet *et al.* (2006) for performance tested Bonsmara bulls. Although SC did not differ significantly between the HE, ME and LE fed bulls, the HE fed bulls were younger and had the largest scrotal circumference. In addition to genotype, Brito *et al*. (2004) also reported differences in SC due to environmental influences. Similarly, Torres-Junior and Henry (2005) indicate that Guzerat, Nelore, Gir, and Brahman bulls, raised under an intensive feeding regime, as well as *Bos taurus taurus* bulls, had greater scrotal circumference measurements at an equivalent age range. Cates (1975) demonstrated that, regardless of the age or breed, the probability of a bull being a satisfactory breeder increased as SC increased. Similarly, Blockey (1980) noted that as breeding pressure increased, bulls with greater SC must be used to maintain acceptable fertility levels. It was further observed by Kennedy *et al.* (2002) that energy levels in diets significantly ($p < 0.05$) influence testicular development in yearling bulls. Pruitt and Corah (1986) established that BCS influenced SC in Simmentaler bulls, since fatter bulls had a larger SC than thinner bulls. Barth and Waldner (2002) and Ellis *et al*. (2005) also noted the loss of scrotal fat depositions associated with a decline in body condition following environmental and management changes. Coulter *et al.* (1987) reported that SC was higher ($p < 0.05$) at 12 months of age in bulls fed high- versus moderate-energy diets after weaning. It seems that part of the increase in scrotal circumference in bulls fed high-energy diets may be the result of additional fat deposition in the scrotum. These results indicate that nutritional effects on SC need to be considered when evaluating bulls for reproductive soundness or when using SC as a selection trait.

Diet influenced seminal quality with semen concentration ($p < 0.001$) and linear movement of sperm ($p < 0.05$) being significantly lower in bulls fed the HE diet. These findings are similar to those reported by Coulter and Kozub (1984) where very poor progressive sperm motility was observed in Hereford bulls fed a high energy diet compared with a medium energy diet. By contrast Breuer (1980), Pruitt (1983) and Mwansa and Makarechian (1991) reported no significant dietary effect on total progressive sperm motility. The results from this study further indicate that bulls fed the HE diet had a lower percentage ($p < 0.001$) live sperm, lower percentage motile sperm ($p < 0.001$) and a higher percentage of dead sperm ($p < 0.001$) in comparison with ME or LE fed bulls (Table 8.2).

Table 8.2 : The effect of high, medium and low energy diets on scrotal circumference (SC), subjective semen concentration (SConS), objective semen concentration (SCon0), mass movement (MV), percentage live sperm (LS), percentage dead sperm (DS), percentage linear movement (LM), semen volume (Vol), major semen defects (MD), minor semen defects (Min D), scrotal fat (S fat) and inactive tubuli (Inac tubuli)

Trait	n	High	n	Medium	n	Low
SC (mm)	18	328.9 ± 5.91^{a}	17	327.2 ± 5.37^{a}	15	323.4 ± 3.64^{a}
SConS (1 – 3)	18	1.3 ± 0.14^{b}	17	2.4 ± 0.18^{a}	15	2.6 ± 0.16^{a}
MV (1 – 5)	18	1.7 ± 0.30^{b}	17	2.2 ± 0.31^{ab}	15	3.1 ± 0.23^{a}
LS (%)	18	38.2 ± 7.22^{b}	17	64.2 ± 6.70^{a}	15	66.3 ± 5.95^{a}
DS (%)	18	61.7 ± 7.22^{a}	17	35.7 ± 6.66^{b}	15	33.6 ± 5.95^{b}
LM (%)	18	25.4 ± 7.63^{b}	17	70.2 ± 6.63^{a}	15	73.8 ± 5.75^{a}
MD (%)	18	27.1 ± 6.82^{a}	17	9.7 ± 1.45^{b}	15	5.4 ± 1.26^{b}
Min D (%)	18	7.4 ± 0.91^{a}	17	5.5 ± 0.87^{ab}	15	3.9 ± 0.58^{b}
Vol. (ml)	18	2.5 ± 0.12^{a}	17	4.1 ± 0.33^{b}	15	4.7 ± 0.15^{b}
SCon0 ($x10^{9}$)	18	1.9 ± 18.67^{a}	17	3.0 ± 10.25^{b}	15	3.6 ± 18.45^{c}
S fat (g)	18	243.4 ± 21.59^{a}	17	110.0 ± 12.1^{b}	15	$88. \pm 9.65^{b}$
Inac tubuli (%)	18	44.8 ± 2.85^{a}	17	8.4 ± 1.66^{b}	15	1.4 ± 0.68^{c}

Rows with different ^{a,b,c} superscripts differ at the $p < 0.05$ level of significance

The total major ($p < 0.001$) and total minor ($p < 0.05$) sperm defects were also greatest in the HE fed bulls (Table 8.2). Coulter and Kozub (1989), Wiltbank and Parish (1986) and Parkinson (2004) reported a negative relationship between sperm morphological defects and bull fertility in natural serving bulls. Coulter and Kozub (1984) observed detrimental effects on epididymal sperm reserves, sperm motility and sperm morphology in 2-year old Hereford bulls fed high levels of energy similar to the level reported in this study for the HE group. In their study Mwansa and Makarechian (1991) also noted a higher percentage of major, minor and total sperm abnormalities in bulls fed high levels of dietary energy. The percentage normal acrosomes were also slightly lower in their study than that for any breed group reported by Pruitt and Corah (1985). While Mann and Walton (1953) and Pruitt and Corah (1985) observed a decreased secretary function of accessory glands in underfed bulls there was no difference in sperm quality. The results from the present study show that the bulls fed the HE diet produced significantly ($p < 0.001$) less semen and seminal fluid compared to bulls fed the lower levels of energy (Table 8.2). These results imply that over feeding could adversely affect semen and seminal fluid production to a greater extent than if a bull is under nourished, because over fed bulls have poorer semen quality than under fed bulls.

Lunstra and Coulter (1997) established that increased scrotal temperatures were correlated with a reduced total number of sperm in the ejaculate. This resulted in lower semen volumes. Such findings are in agreement with reports that high testicular temperatures result in reduced sperm production (Coulter *et al.,* 1997). This could explain the lower volumes of semen obtained in bulls fed the HE diet. It is possible that abnormal temperature control of the testis occurred as a result of increased fat deposition in the neck of the scrotum. Chacon *et al.* (1999) did not find a correlation of SC and sperm morphology in extensively managed bulls similar to those of the LE group in this study. However, the results from this study are consistent with those reported by Coulter *et al.* (1997) in which the seminal quality of bulls with a higher body condition score was inferior to that of bulls with a lower body condition score. Pruitt and Corah (1985) reported that diet did not influence reproductive capacity in Simmentaler bulls fed medium levels of energy, but semen volume was affected by diet. However, it seems that the moderate energy diet reported in that study was much higher than the medium energy levels used in this study.

The results of the histological examination of the testis of bulls fed the different energy diets are represented in Table 8.2. Dietary energy level significantly ($p < 0.05$) influenced live weight, which in turn is positively correlated to SC ($r = 0.51$) and percentage inactive seminiferous tubuli. Bulls fed the HE diet had 36% more seminiferous tubules classified as inactive as those fed the ME and LE diet. The high percentage inactive seminiferous tubules could be ascribed to 2 bulls in the HE group that were classified as sterile at a histological level. Bulls fed the HE diet showed greater variability in size, with a number of tubuli demonstrating severe atrophy, which laced most of the layers of reproductive cells. The remaining cells were most probably Sertoli cells that had undergone fatty degeneration. Marked fibrosis surrounded some of the seminiferous tubuli, while groups of atrophied interstitial cells were present in a number of the seminiferous tubuli of bulls fed the HE diet. Similar results were reported by Marcus *et al.* (1997), who observed that a significant amount of morphologically abnormal spermatozoa were produced in cryptorchid bulls showing similar symptoms. Therefore, excessive fat deposition in the scrotum affects normal cell division processes of the testicular tissue in bulls fed high levels of energy.

Scrotal fat deposition was significantly higher ($p < 0.05$) in bulls fed the HE diet compared to those fed the ME and LE diets. Similar results were reported by Coulter *et al.* (1997) in Hereford and Simmentaler bulls fed a medium and high energy diet. Moreover, Pruitt and Corah (1985) noted that reversing the nutritional planes did not reduce the inguinal fat content to any extent. Furthermore, Coulter *et al.* (1997) reported greater variation in scrotal surface temperatures in HE fed bulls due to fat deposition in the scrotum. It may be that bulls on the high energy diet were unable to cool the scrotum as well as those on the moderate energy diet, due to fat deposits in the neck of the scrotum, pampiniform plexus and scrotal tissue (Coulter, 1988). Such fat deposits may decrease the capacity for counter current heat exchange within the testicular vascular cone (Cook *et al.,* 1994). In a related study conducted by Kastelic *et al.* (1996) simulating the effect of fat deposited within the scrotal neck by insulation of the scrotal neck, resulted in a decrease in morphologically normal sperm. This appeared to be the results of increased scrotal subcutaneous and intra-testicular temperatures. Perhaps the thermoregulatory mechanism which maintains the testis at ideal temperatures may be overwhelmed by increased scrotal insulation. This then result in a decreased seminal quality, which could further explain the poor seminal quality obtained in the bulls fed the HE diet in this study. These results are also in agreement with that reported by Bath and Oko (1989) and Cook (1994) who observed similar effects of thermoregulation on semen quality. Similarly Chacon *et al.* (1999) reported that increased temperatures and humidity, as often experienced in the tropical regions, increased the percentage of abnormal spermatozoa in beef bulls, suggesting that the environment can affect epididymal functions. The combined effect of environmental conditions and increased fat deposition in the scrotum could limit scrotal thermoregulation even further and cause substantially more major and minor spermatozoa abnormalities.

The relationship between the traits measured in this study was tested within and across the different dietary treatment groups. Correlation coefficients between SC and growth traits were generally favourable for the different dietary treatments. Correlations between live weight and SC were 0.51, 0.45 and 0.52 ($p < 0.05$) for the HE, ME and LE groups respectively, while a slightly lower correlation ($r = 0.39$, $p < 0.05$) was found when the data was pooled. Other researchers reported similar relationships when SC was not adjusted for age (Coulter and Foote, 1977, Lunstra *et al.,* 1978, Fields *et al.,* 1982, Pruitt and Corah, 1986, Torres-Junior and Henry 2005). When adjusted for age, Pruitt and Corah (1986) found a lower correlation ($r = 0.31$) between live weight and SC in their study. SC was shown to have a higher positive relationship with ADA ($r = 0.24$, $p = 0.084$) than ADG ($r = 0.15$, $p = 0.27$) in this study. Johnson *et al.* (1974) also reported a high correlation between pre-weaning growth and testicular development in beef bulls. Hoogenboezem and Swanepoel (1995) stated that bulls with inferior testicular development at a young age showed an increase in SC as both age and body weight increased. However, those bulls with superior development at a relatively young age maintained that advantage throughout life. The relationship between SC and growth traits observed for bulls during performance tests on high energy diets, agrees with that observed in other studies (Bourdon and Brinks, 1986).

Therefore, it is possible that independent selection for SC is compatible with selection for growth.

SC was generally positively correlated with BCS and carcass dressing percentage, but the only significant ($p < 0.05$) relationship was between SC and carcass dressing percentage in the bulls fed the ME diet ($r = 0.46$), This indicates that bulls with a higher BCS and carcass dressing percentage generally had a higher SC and this implies that more fat is deposited within the scrotum and scrotal tissue as the condition of the animal increases. Pruitt and Corah (1986) established that BCS influenced SC in Simmentaler bulls, since fatter bulls had a larger SC than thinner bulls. Coulter *et al.* (1987) reported that SC was higher ($p < 0.05$) at 12 months of age in bulls fed high- versus moderate-energy diets after weaning. The higher relationship observed in this study between SC and carcass-dressing percentage could be ascribed to the measuring methods. BCS is a subjective method of measuring while carcass-dressing percentage is an objective method, which should be more accurate. Also, a lack of significance in the relationship between BCS and SC in the different dietary treatments, or when the data was pooled was surprising, because bulls fed high energy diets have been reported to have greater SC. Coulter and Kozub (1984) reported a result similar to that obtained in this study when high-energy diets were fed to Hereford and Angus bulls. BCS is indicative of body live weight in the bull (Elmore *et al.,* 1976, Coulter and Foote, 1977, Carter *et al.,* 1980). Body weight was significantly correlated ($p < 0.001$) to BCS ($r = 0.70$), carcass-dressing percentage ($r = 0.60$), ADG ($r = 0.80$), ADA ($r = 0.90$) and SC ($r = 0.39$, $p < 0.05$).

The results obtained in this study support the findings by Mwasa and Makarechian (1991) who stated that the rate of fat deposition would significantly influence rate of increase in SC. The relationship between SC and live weight in bulls fed the LE diet ($r = 0.51$, $p < 0.05$) indicates that live weight is a better predictor of SC when bulls are fed low energy diets than when bulls are fed medium and high energy diets. Within treatment groups trends were towards a negative association between BCS and progressive sperm motility in bulls fed HE diets ($r = -0.54$, $p < 0.05$). A negative non-significant relationship was noted in bulls fed the ME diet ($r = -0.024$, $p = 0.92$), while a positive non-significant relationship was recorded in those fed the LE diet ($r = 0.087$, $p = 0.75$). The results from this study show similar trends compared to those observed by Coulter and Kozub (1984), who reported a favourable relationship between back fat thickness and progressive semen movement in ME fed bulls while a negative relationship was observed in bulls fed HE diets.

Within diet groups the percentage live sperm was correlated with mass movement ($r = 0.49$, $p = 0.063$) in LE fed bulls, ME ($r = 0.86$, $p < 0.001$) and ($r = 0.90$, $p < 0.001$) for the HE fed bulls. When the data were pooled the positive relationship was still strong ($r = 0.81$, $p < 0.001$). The percentage live sperm was also correlated with linear motility in LE ($r = 0.94$, $p < 0.001$), ME ($r = 0.81$, $p < 0.001$) and pooled data ($r = 0.38$, $p < 0.001$). Percentage linear motility was generally favourably correlated with mass movement of sperm within the lower energy diet groups (LE; $r = 0.50$, $p < 0.05$ and ME; $r = 0.76$, p

< 0.05), but no significant relationship could be obtained in the HE group. However, when the data were pooled a positive relationship was obtained between linear motility and mass movement of sperm (r = 0.50, p < 0.001). The percentage dead sperm was generally negatively correlated (favourable) with mass movement of sperm (Table 8.3).

Table 8.3 : The relationship (Pearson's rho correlation) between the percentage dead sperm and mass movement of sperm (MV), percentage live sperm (LS), and percentage linear motility of sperm (LM) for the low energy (LE), medium energy (ME), high energy (HE)

Trait	LE		ME		HE		PD	
	r	Pr>F	r	Pr>F	r	Pr>F	r	Pr>F
MV (1-5)	-0.49	0.06	-0.86	0.001	-0.90	0.001	-0.81	0.001
LS (%)	-1.0	0.001	-0.99	0.001	-1.0	0.001	-0.99	0.001
LM (%)	-0.94	0.001	-0.81	0.001	-0.99	0.002	-0.58	0.001

The percentage major seminal defects was negatively correlated with live weight in bulls fed the LE diet (r = -0.46, p = 0.008) and ME diet (r = -0.41, p = 0.08), while this characteristic was negatively correlated with mass movement of sperm (r = -0.63, p < 0.05) and percentage live sperm (r = -0.61, p < 0.05) in HE fed bulls. When the data was pooled the percentage major seminal defects was negatively correlated with mass movement of sperm (r = -0.46, p < 0.05), percentage of live sperm (r = 0.52, p < 0.001) and percentage linear sperm movement (r = -0.36, p < 0.05), and a positive (unfavourable) relationship with BCS was reported (r = 0.42, p < 0.05). From the results obtained in this study, SC correlated favourably with the percentage live sperm in bulls fed the LE diet ($r = 0.47$, $p < 0.07$), HE diet ($r = 0.44$, $p < 0.05$) and pooled data ($r = 0.30$, $p < 0.05$).

Correlation coefficients between scrotal circumference and seminal characteristics have generally been variable in the literature (Pruitt and Corah, 1985, Coulter and Kozab, 1989, Mwansa and Makarechian, 1991, Coulter, 1994, Parkinson 2004). Results from this study indicate that increased body weight and BCS increased the percentage of dead sperm and percentage major semen defects, and decreased the percentage live sperm, mass movement of sperm and progressive linear movement of sperm. It seems as if SC is generally not an adequate indicator of the percentage live sperm in highly conditioned young bulls, which does not agree with studies conducted by Brinks *et al.* (1978), Knights *et al.* (1984) and Brinks (1994). Coulter and Kozub (1989) observed similar tendencies as those obtained in this study, and also reported a negative relationship between back fat thickness and bull fertility in a multiple-sire breeding program with young beef bulls. By contrast Pruitt and Corah, (1985), fed three different levels of dietary energy to Hereford and Simmentaler bulls, and observed no significant effect on seminal characteristics. It should be noted that although there was no significant effect of dietary energy level in their study, the percentage of progressively motile spermatozoa, amount of morphologically abnormal spermatozoa and aged acrosomes in the Hereford bulls suggest that the bulls may have been affected detrimentally by the diets fed.

8.5 CONCLUSION

The results of this study suggest that if breeders are to place emphasis on traits that are associated with reproductive fitness such as SC which is associated with semen quality, then it is prudent that these associated traits accurately represent the desired trait. Caution should be taken when interpreting SC as an indicator of reproductive fitness in young bulls when they are fed high levels of nutrition. Although SC is positively correlated with growth, under these conditions SC generally is not an acceptable indicator of reproductive fitness as bulls on the HE diet had greater SC but were also the group of bulls for which the histological examinations showed the greatest degeneration of seminiferous tubules and associated semen quality. The negative association between SC and seminal traits of bulls fed the HE diet is probably due to the detrimental effects of excessive fat deposits in the scrotum and scrotal tissue, affecting normal scrotal thermoregulation mechanisms. Therefore, it seems possible that feeding high-energy diets to young beef bulls not only reduces sperm production and seminal quality, but could ultimately affect bull fertility permanently.

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