CHAPTER 9

RELATIONSHIP BETWEEN SCROTAL CIRCUMFERENCE, QUANTITATIVE TESTICULAR TRAITS AND GROWTH PERFORMANCE IN TROPICALLY ADAPTED YEARLING BEEF BULLS DIFFERING IN AGE

9.1 ABSTRACT

The aim of the study was to investigate the relationship between testicular size and histology, sperm production traits and growth traits in tropically adapted yearling beef bulls. The bulls were fed a high energy diet and the effect on average daily gain (ADG), average daily gain per day of age (ADA), body condition score (BCS), feed conversion efficiency (FCE), scrotal circumference (SC), seminal traits and testicular histology were examined in Bonsmara bulls (n = 34). The high energy diet contained not less than 11 MJ ME / kg DM and 13.8% CP. Bulls were fed the HE diet from an average starting age of either 210 (YB; n = 17) or 257 days (OB; n = 17) for a total of 112 days. Despite the age difference, growth and carcass traits were similar for the bulls irrespective of starting age. Scrotal weight, scrotal skin weight and scrotal skin thickness were greater ($p < 0.001$) in the YB (2223.4 ± 11.68 g, 576.6 ± 25.17 g and 4.5 ± 0.15 mm) compared to that of the older group (1010.15 ± 50.10 g, 255.9 ± 13.55 g and 4.0 ± 0.13 mm). The weight of the epididymal / spermatic cord (WESC) was higher ($p < 0.05$) in the older bulls (70.2 ± 3.53 g) compared to that of the younger group (47.2 ± 3.17 g) with a similar trend observed when the volume of the epididymal / spermatic cord (VESC) was measured. Scrotal fat deposition was significantly ($p < 0.001$) increased by initial age (YB = 1164.7 ± 102.20 g vs OB = 263.5 ± 27.52 g).

Age of the bulls also influenced ($p < 0.05$) the percentage inactive seminiferous tubuli, with the young bulls having 9.7% more seminiferous tubules classified as inactive compared to the older bulls. Seminal quality showed a similar trend and was generally of a lower standard than that of the group tested at an average of 369 days of age. Semen concentration ($p < 0.05$) and percentage linear sperm motility ($p < 0.08$) were the traits most affected by age. A negative correlation was evident between BCS and testis weight ($r = -0.51$, $p = 0.0342$), testis volume ($r = -0.52$, $p = 0.0318$) and SC of dissected testis ($r = -0.49$, $p = 0.042$) in the young bulls. Correlation coefficients between SC and testis traits such as testis weight and testis volume were high ($p < 0.05$) for both the groups (YB; $r = 0.87$ and $r = 0.87$ and OB; $r = 0.77$ and $r = 0.81$). The relationship between SC and scrotal fat ($r = 0.85$) was highly significant ($p < 0.001$) only in the younger group. The results suggest that when bulls are fed a high energy diet the age at which such feeding commences is of importance as regards their subsequent fertility.

9.2 INTRODUCTION

High levels of energy intake could affect reproductive performance of young bulls used for natural mating by a direct effect on the rate of sexual development (Pruitt and Corah, 1985, Parkinson 2004, Torres-Junior and Henry 2005). At the other end of the scale diets deficient in protein and energy generally result in extreme weight loss and may adversely affect libido in bulls (Meacham *et al.,* 1963). However, feeding high-energy diets to young bulls is a common practice for producers finishing bulls for shows, sale and performance testing purposes. Feeding diets high in energy has been reported to have favourable effects on the expression of genetic potential for growth rate in young bulls (Gillespie 1983), on growth and carcass characteristics (Woody *et al.,* 1983) and on feed efficiency (Price *et al.,* 1984). Unfortunately, these diets have been reported to reduce the reproductive potential of young bulls (Coulter and Kozub 1984, Mwansa and Makarechian, 1991, Coulter 1994, Parkinson 2004). The use of scrotal circumference as a selection tool to increase reproductive performance has been prompted by studies showing that bulls with larger SC produce more sperm (Hahn *et al.,* 1969, Foote *et al.,* 1977, Arteaga *et al.,* 2001, Kastelic *et al.,* 2001), produce higher semen quality (Cates 1975, Fields *et al.,* 1982, Parkinson 2004) and are younger at puberty (Lunstra *et al.,* 1978, Brito et al., 2004, Parkinson 2004). Brinks *et al.* (1978) and King *et al.* (1983) demonstrated a favourable correlation between SC and age at puberty in half-sib heifers, but Pruitt and Corah (1986) established that higher levels of energy increased SC, without resulting in earlier puberty. This indicates that nutritional treatments that increase SC do not necessarily hasten sexual development. It follows that SC is not necessarily a good indicator of puberty across different energy levels.

Many reports have provided information on changes in testicular size associated with growth and aging in bulls (Almquist *et al.,* 1976, Elmore *et al.,* 1976, Coulter and Foote 1979, Vilakazi and Webb 2004, Brito *et al.,* 2004, Torres-Junior and Henry 2005) and the onset of puberty in young bulls (Fields *et al.,* 1982, Troconiz *et al.,* 1991, Jimėnez-Severiano 2002, Lunstra and Cundiff, 2003). Furthermore, Aponte *et al.* (2005) noted that regardless of apparent differences within breeds, *Bos taurus* breeds had spermatozoa in the lumen of the seminiferous tubules at 8 months of age, 1 and half months before spermatogenesis started in Brahman bulls (*Bos Indicus*). Kennedy *et al.* (2002) and Jimėnez-Severiano (2002), noted that significantly less 10 month old bulls were classified as satisfactory breeders than bulls at 11 -15 months of age. From these reports it is evident that semen production and quality are influenced by age and breed of the bull. Vilakazi and Webb (2004) noted that bulls aged between 3 and 4 years of age produced better sperm, with less morphological defects than bulls younger than 3 years and older than 5 years of age. Coulter and Foote (1979) reported that as bulls age the positive (favourable) correlation between SC and semen production and quality decreased, which is associated with an increase in fibrotic and tumorous tissue in the testis.

It would seem that the period between 8 to 24 months of age in bulls is the time span that represents a progressive continuum of physical and sexual maturation processes. At this time rapid increases in both body and testicular weight occur and at this stage of sexual development is where the testis may be particularly vulnerable to factors that influence fertility especially during the pre-pubertal period. The objective of this research was to study whether the effect of a HE diet on the production performance, semen quality and testicular histology of beef bulls was influenced by age at which such HE feeding commenced.

9.3 MATERIALS AND METHODS

From a pool of 54 Bonsmara bulls submitted for performance testing 34 bulls were selected and fed a high energy diet (HE) at a test centre near Bloemfontein, South Africa. The bulls were divided into two equally sized groups based on the age at the start of the test period (OB = 257 days old: YB = 210 days old) when a HE diet was offered.

Only bulls meeting preconditioning requirements and physical inspection as prescribed by the South African Beef Cattle performance-testing scheme were included in the analysis (bulls between 150 and 270 days of age qualify to be performance tested). Both groups of bulls were fed intensively on a high-energy (HE) diet for 84 days, following a 28-day adaptation period (112 days in total) before commencing with the data collection. The high energy ration was offered *ad libitum* in a pellet form and contained a minimum of 11 MJ/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) . They were penned in an open front barn fitted with a feed station (milkrite) and transponders in order to measure individual feed intake and feed conversion efficiency of the bulls.

Performance data recorded were weights at the start and end of the intensive feeding, average daily gain (ADG) over the 84 days intensive feeding programme, average daily gain per day of age (ADA), body condition score (BCS), feed conversion efficiency (FCE), scrotal circumference (SC) and the average age of the bulls. FCE was determined by the amount of feed required (kg) to produce 1kg of weight gain, expressed as a ratio. BCS was recorded at the end of the 84^{th} day trial period and assessed using the 1 – 5 scoring system as described by Taylor and Swanepoel (1999). Bulls were weighed and measured weekly.

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 in all the bulls at the end of the test period. The bulls were considered as having reached puberty in both the bull age groups, although puberty is often defined as the first time a bull produces an ejaculate with at least 50×10^6 spermatozoa / ml with at least 10% progressively motile spermatozoa (Ball *et al.,* 1983). Bulls were also considered as having reached puberty at a SC measurement of 26.1 ± 0.2 cm (Coulter *et al.,* 1986), which is relatively consistent among breeds differing widely in age and weight at puberty (Lunstra *et al.,* 1978, Kennedy *et al.,* 2002).

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). 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. The Breeding Soundness examination (BSE) endorsed by the society of Theriogenology (Ball *et al.,* 1983, Chenoweth *et al.,* 1993) served as the guidelines for the evaluation of spermatozoa. Total volume of the ejaculate was measured using a calibrated test tube, but this measurement was not used in the analysis due to inconsistent collection procedures associated with accessory glandular secretion during the collection process. Mass movement was evaluated on a 1 to 5 scale (0 = no movement; 1 = random movement of individual spermatozoa; 2 = slight progressive movement; 3 = slight wave movement; 4 = pronounced 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 diluted 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 was completed the bulls were slaughtered on the same day and the carcass dressing percentage (CDP), weight of the warm carcass (WCW), weight of the cold carcass (WCC) and carcass fat thickness (CFT) were determined. Following retrieval of the testes at slaughter, six parenchyma samples per bull were taken form the dorsal, middle and ventral portions of each testis, fixed in Bouin's solution for 24 to 48 hours, trimmed, loaded in cassettes and stored in 70% alcohol until processing. The tissue samples were processed by standard tissue preparation techniques. 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), but for analysis purposes 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 tubules classified as inactive could have contained spermatogonia, it is believed that they were not producing spermatocytes or that the spermatocytes had been lost because of damage prior to procurement of testicular parenchyma. With testicular degeneration, the first histological noticeable effect is on the primary spermatocytes, regardless of the testicular insult (Coulter, 1994). However, before the commencement of the histological analysis of the parenchyma tissue the fat surrounding the testis in the scrotum was dissected and weighed (SF) together with recording scrotal skin weight (SSW), weight of left (WLT) and right (WRT) testicles, total scrotal weight

(TSW), weight of the epididymis and spermatic cord (ESC), circumference of the dissected left (CLT) and right (CRT) testicles, scrotal skin thickness (SST) and the volumes of left and right testicles as well as the volume of the epididymal / spermatic cord using a volumetric measuring beaker and water.

Data were analysed as a one-way analysis of variance with age as the main effect using PROC GLM (SAS, 1995) to determine significant difference relating to the dependent variables. Tukey's HSD was used to test for differences between age means, while normality within age, 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 age groups. Correlations between the dependent variables were determined by employing the Pearson's rho.

9.4 RESULTS AND DISCUSSION

The results of the growth and carcass traits of bulls fed a HE diet at two different ages are presented in Table 9.1. The results on the male reproductive organs for the two age groups of bulls are summarized in Table 9.2. The effects on seminal traits are presented in Table 9.3 for the two age groups of bulls fed the HE diet. The improved growth rate ($p < 0.001$) of the younger bulls resulted in 11.4 kg live weight advantage at slaughter. This advantage did improve the body condition score, but not significantly so ($p < 0.06$, Table 9.1). These unexpected results for the young bulls were higher than those reported by Coulter and Kozub, (1984). In general, the physical characteristics of the testes and associated tissues followed a trend that could be related to the improved growth performance of the young bulls (Table 9.2). The scrotal circumference (SC) did not differ significantly between age groups. In fact, the younger group of bulls had on average a 10.86 mm advantage over the older group of bulls, with regards to SC (Table 9.2), but this difference was not significant.

Table 9.1 : Means and standard errors (±SEM) for age at slaughter (AAS), live weight (LW), average daily gain (ADG), average daily gain per day of age (ADA), feed conversion efficiency (FCE), body condition score (BCS), carcass weight warm (CWW), carcass weight cold (CWC), carcass dressing percentage (CDP), carcass fat grade (CFG) and body condition score (BCS)

	OLDER BULLS (OB)			YOUNGER BULLS (YB)			
VARIABLE	**N**	**MEAN**	**±SEM**	**N**	**MEAN**	**±SEM**	**Pr > F**
AAS (days)	17	369.5	3.50	17	322.2	4.72	0.0001
LW (kg)	17	373.4	7.15	17	384.8	8.64	0.5848
ADA (g)	17	997.7	12.33	17	1073.2	22.48	0.0012
ADG (g)	17	1680.2	38.49	17	1504.2	53.22	0.0010
FCE (ratio)	17	6.1	0.20	17	6.3	0.17	0.4350
CWW (kg)	17	215.5	4.22	17	213.5	5.61	0.8564
CWC (kg)	17	205.6	6.19	17	207.1	5.44	0.7991
CDP (%)	17	56.1	0.79	17	55.8	0.46	0.3234
CFG (1-5)	17	2.0	0.15	17	2.1	0.12	0.2178
BCS (1-5)	17	3.6	0.07	17	3.9	0.05	0.0654

Almquist *et al.* (1976), Mwasa and Makerechian (1991), Kennedy *et al.* (2002) and Torres-Junior and Henry (2005) found age of bulls a significant source of variation for scrotal circumference. Morrow *et al.* (1981) Kennedy *et al.* (2002) and Ellis *et al.* (2005) observed that energy levels in diets significantly influence testicular development in yearling bulls. Furthermore, Pruitt and Corah (1986) established that BCS has an influence on SC in Simmentaler bulls, with fatter bulls having larger SC than thinner bulls. They state further that nutritional treatments that increase SC did not necessarily hasten sexual development and improve fertility and that live weight is a more accurate predictor of SC than age. Furthermore, Thompson and Johnson (1995) reported that earlier calving in the female progeny was not associated with scrotal size or with interactions of scrotal size and age of bulls that are performance tested. Although the YB group were regarded as having reached puberty based on accepted SC norms, it is possible that these bulls were not physiologically as mature as bulls with similar SC measurements that were not performance tested.

When attention is focused on what the scrotum actually contains, it is evident that, the physical characteristics of the testes (weight scrotum, weight and thickness of the scrotal skin) favoured the young bulls that grew more rapidly (Table 9.2). In sharp contrast, the quality of associated tissues (epididymal spermatic cord, percentage inactive tubuli, sperm concentration, sperm motility and sperm defects) was to the advantage of the older group of bulls (Table 9.2). By limiting attention to the testicular tissue it is seen that there was no visible effect due to age of bulls (Table 9.2). The important finding in this study is that although, the young bulls showed a greater scrotal circumference than those 47 days older on average at the end of the HE feeding, the scrotum was clearly packed with fat to the detriment of tissue required for spermatozoa production (Table 9.2). This may be detrimental towards fertility, because Coulter and Kozub (1989), Coulter *et al.* (1987), Coulter and Baily (1988), Coulter (1994) and Barth (1997), reported a negative relationship between back fat thickness and bull fertility. As indicated by BCS (Table 9.2) the tendency for the YB group to deposit more total body fat than the OB group approached significance ($p < 0.06$). Almquist *et al.* (1976), Mwasa and Makerechian (1991) and Chacon et al. (2002) reported that scrotal circumference of bulls increased with age. Wiley *et al.* (1971) and Morrow *et al.* (1981) observed that energy levels in diets positively influence testicular development in yearling bulls. Their assessments were based on scrotal circumference which has now been shown to be only part of the answer.

Although, epididymal sperm reserves were not measured in this study, WESC weight and VESC volume, provide an indication of expected epididymal sperm reserves (ESR). Coulter and Kozub (1984) reported a reduction in the ESR of bulls fed high-energy diets, while Wilsey (1972) established that feeding a high-energy diet had no significant effect on either daily sperm production or total ESR in yearling bulls. However, the diets compared by Wilsey resulted in a difference in back fat thickness that was much less than that observed in this study or that reported by Coulter and Kozub (1984). Coulter *et al.* (1983) reported a reduction in daily sperm output in 15-month old bulls fed high- energy diets, which could be explained only by a reduction in ESR, because re-absorption of significant numbers of sperm within the epididymis of the bull is not common (Amann *et al.,* 1976). A potential mechanism responsible for the reduction in ESR is the inability of thermoregulation of the scrotal contents (Harrison, 1975), due to the isolative effects of increased scrotal lipid and fat deposition of fat around the pampiniform plexsus (Coulter and Kozub, 1984). The reduction in ESR as measured by the WESC weight and VESC volume in this study was more evident in the younger bulls and may be due to a reduced testicular sperm production capacity.

Table 9.2 : Means and standard errors (±SEM) for scrotal circumference (SC), scrotal weight (SW), scrotal skin weight (SSW), scrotal skin thickness (SST), left testis circumference (LTC), right testis circumference (RTC), total testis circumference (TTC), weight of left testis (WLT), weight of right testis (WRT), volume of left testis (VLT), volume of right testis (VRT), total testis volume (TTV), weight of epididymal spermatic cord (WESC), volume of the epididymal spermatic cord (VESC), scrotal fat (SF) and percentage inactive tubuli (PIT)

	OLDER BULLS (OB)			YOUNGER BULLS (YB)			
VARIABLE	n	MEAN	±SEM	n	MEAN	±SEM	Pr > F
SC (mm)	17	329.9	5.10	17	331.7	6.49	0.7495
SW (g)	17	1010.1	50.10	17	2223.4	117.68	0.0001
SSW (g)	17	255.9	13.55	17	476.6	25.17	0.0001
SST (mm)	17	4.0	0.13	17	4.5	0.15	0.0216
LTC (cm)	17	17.1	0.35	17	17.3	0.49	0.6743
RTC (cm)	17	16.9	0.01	17	17.0	0.47	0.8290
TTC (cm)	17	34.2	0.28	17	34.2	0.93	0.8878
WLT (g)	17	211.7	14.06	17	224.0	21.09	0.5585
WRT (g)	17	210.4	12.10	17	214.1	12.81	0.7596
VLT (ml)	17	205.2	11.55	17	216.4	22.31	0.4089
VRT (ml)	17	201.5	13.01	17	201.2	14.70	0.9929
TTV (ml)	17	406.7	24.75	17	417.7	36.41	0.6366
WESC (g)	17	70.2	3.53	17	47.2	3.17	0.0001
VESC (ml)	17	59.4	3.03	17	48.8	2.70	0.0013
SF (g)	17	263.5	27.52	17	1164.7	102.20	0.0001
PIT %	17	38.4	3.05	17	47.1	1.15	0.0459

It is generally accepted that SC accurately reflects testis weight, which in turn is related to direct measures of fertility such as spermatogenesis (Entwistle, 1992, Gazzola *et al.,* 2000, Parkinson, 2004). However, in the present study testicular weight and volume were found not to differ significantly between the OB and YB groups. Thus, on the basis of SC alone, it would appear that feeding level alone did not influence spermatozoa production. However, Coulter and Kozub (1984) observed that the paired testis weight (PTW) was lowest in Hereford bulls fed a high-energy diet. They further stated that because no difference was observed in PTW between high and medium energy fed bulls, and yet high energy fed bulls had larger SC than medium energy fed bulls, those fed a high energy diet may deposit more fat, within the scrotum. This would inflate the SC measurement and thus, introduce an error in predicted PTW. A similar trend was observed in this study and seems to have a greater influence on young bulls than on older bulls when high-energy diets are fed.

The findings of high levels of scrotal fat in the young bulls (Table 9.2) is supported by Coulter *et al.* (1997) who reported a significant increase in scrotal fat of bulls fed high energy diets compared to bulls fed medium and low energy diets. The amount of fat deposited in the scrotum of the YB group in the present study is higher than that reported in the literature. It seems that feeding high energy diets to bulls at a young age causes more fat deposition in the scrotum than feeding high energy diets to bulls at an older age. Coulter (1997) observed greater variation in scrotal surface temperatures in HE fed bulls, due to fat deposits in the neck of the scrotum, pampiniform plexus and scrotal tissue (Coulter, 1988). This increased fat deposition in the scrotum decreases the capacity for counter current heat exchange within the testicular vascular cone (Cook *et al.,* 1994). It seems that the thermoregulatory mechanism maintaining the testis at ideal temperatures may be overwhelmed by increased scrotal insulation, resulting in decreased seminal quality.

Increased fat deposits in the scrotum of the bulls in this study could explain the poor seminal results obtained, which tended to increase as fat deposition in the scrotum increased as demonstrated in the results of the YB group.

Age of the bulls significantly ($p < 0.04$) influenced the percentage inactive seminiferous tubuli when a high-energy diet was fed. The YB group had 8.7% more seminiferous tubules classified as inactive compared to the OB group. The high percentage inactive seminiferous tubules could be ascribed to the two bulls in the OB group and three bulls in the YB group being classified as sterile. The YB group also had a greater number of tubuli demonstrating severe atrophy and degeneration of the reproductive cells lining the seminiferous tubules compared to the OB group. As a result both groups of bulls demonstrated a high percentage of morphologically abnormal spermatozoa, similar to that reported by Marcus *et al.* (1996) in cryptorchid bulls. The reason why 5 of 34 bulls were found to be sterile is open to speculation but the high proportion is perturbing.

Age had a limited influence on seminal quality in bulls fed a high-energy diet (Table 9.3). Although this characteristic of the YB group was generally of a lower standard than that of the OB group, semen concentration ($p < 0.05$) and percentage linear sperm motility ($p < 0.08$) were the traits most affected by age. The YB group had lower semen concentration (1.0 ± 6.20 versus 1.4 ± 0.01), sperm counts (19.2 ± 10.40 versus 38.9 ± 8.20) and percentage linear sperm motility (12.9 ± 6.73 versus 27.5 ± 6.70) compared to the OB group respectively. Both groups of bulls in this study had lower semen counts than the 27.9 x 10^6 sperm/ml; SC = 23.9 cm and 28.8 x 10^6 sperm/ml; SC = 27.4 cm in Angus and Hereford bulls at puberty by Lunstra et al. (1978), or the 91.7 x 10^6 sperm/ml reported by Troconiz et al. (1991) with an average SC of 26 cm in Nellore bulls at puberty. Based on SC alone (Table 9.2) the bulls had reached puberty. The poor semen quality observed in both groups of bulls maybe due to the rate of fat deposition in the scrotum of bulls fed high energy diets, which seems more pronounced at a younger age. The results from this study are consistent with those reported by Coulter *et al.* (1997) in which the seminal quality of bulls with a better body condition was inferior to that of bulls with a poor body condition, as a result of fat being deposited in the scrotal neck and tissue (Coulter 1988, Kastelic *et al.,* 1996), which decreases the capacity for counter current heat exchange (Kastelic *et al.,* 1996) and heat dissipation (Coulter, 1995). Contrary to these findings, Mwansa and Makare-chian (1991) reported a reduction in sperm abnormalities and an increase in total progressive sperm motility of bulls at 13.5 months compared with 11.5 months of age when fed a high energy diet. However, Coulter and Kozub (1984) observed detrimental effects on sperm motility and sperm morphology in 2-year-old Hereford bulls fed high levels of energy. Other studies (Bath and Oko 1989, Cook 1994, Coulter 1994) have observed similar effects on semen quality. Regardless of whether lower semen quantity and quality is expected in yearling bulls, it is possible that the pathogenesis of testicular degeneration presented in this study, indicates a degenerative effect on the primary spermatocytes which affects secondary spermatogenesis resulting in an increased number of sperm defects, ultimately reducing fertility of the bulls. Histology of the testis from both the OB and YB age group of bulls indicate diverse levels of atrophy of the seminiferous tubule with greater degrees of atrophy observed in those of the YB group. Furthermore, at histological level it would seem that the damage to the spermatogonium producing cells to be of a permanent nature.

Table 9.3 : Means and standard errors (±SEM) for sperm concentration (Scon), sperm mass movement (SMM), percentage live sperm (PLS), percentage linear sperm motility (PLSM), percentage major sperm defects (PMSD), percentage minor sperm defects (PMISD) and sperm count (Scount)

	OLDER BULLS (OB)			YOUNGER BULLS (YB)			
VARIABLE	**n**	**MEAN**	**±SEM**	**n**	**MEAN**	**±SEM**	**Pr > F**
Scon (1-3)	17	1.4	0.01	17	1.0	0.20	0.006
SMM (1-5)	17	1.8	0.30	17	1.4	0.39	0.145
PLS (%)	17	38.9	8.20	17	17.3	8.14	0.086
PLSM (%)	17	27.5	6.70	17	12.9	6.73	0.001
PMSD (%)	17	28.1	6.90	17	39.1	6.20	0.201
PMISD (%)	17	7.4	0.90	17	7.5	0.88	0.960
Scount ($x10^6$)	17	39.8	17.10	17	19.2	10.40	0.003

9.5 CORRELATIONS

Table 9.4 : Correlation (Pearson's rho correlation) of scrotal circumference with body growth and testes characteristics.

Trait	**Old bulls**		**Young bulls**	
	r	**pr > F**	**r**	**pr > F**
Live weight (kg)	0.51	0.02	0.14	0.57
Warm carcass weight (kg)	0.43	0.07	0.22	0.42
Cold carcass weight (kg)	0.43	0.07	0.22	0.42
Testes weight (g)	0.77	0.001	0.87	0.001
Testes volume (cm^3)	0.81	0.001	0.87	0.001
Scrotal fat (g)	0.29	0.26	0.85	0.001

Correlation coefficients between SC and live and carcass weight tend to be favourable for the OB group fed a HE diet but, not for the young group (Table 9.4). Bourdon and Brinks (1986), Pratt *et al.* (1991), Maiwashe *et al.* (2002) and Parkinson (2004) also reported favourable relationships between SC and growth traits. From the data in Table 9.4, it seems that feeding HE diets to bulls at a young age may increase SC but have little association with the normal growth traits that are measured. Contrary to this other researchers (Coulter and Foote, 1977, Lunstra *et al.,* 1978, Fields *et al.,* 1982) have reported favourable correlations between SC and growth traits in bulls. Prait and Corah (1986) established that BCS influence SC in bulls, since fatter bulls had a larger SC than thinner bulls, while Coulter *et al.* (1987) reported that SC was higher at 12 months of age in bulls fed high versus moderate energy diets after weaning. The results from this study support these findings, and it seems the effect on scrotal circumference of fat deposition as a result of higher BCS in YB fed HE diets is more evident than at an older age. Coulter *et al.* (1977) reported that part of the increase in SC in bulls fed high-energy diets may be ascribed to additional scrotal fat deposition. This is further supported by the negative correlation between BCS and testis weight (r = -0.51, p = 0.034), volume of testis (r = -0.52, p = 0.031) and SC of dissected testis (r = -0.49, p = 0.04) observed in the YB group, while no significant correlation between BCS and SC was observed in the OB group. The lack of a significant correlation between BCS and SC was surprising, because bulls fed HE diets have been reported to have greater SC (Wilsey, 1972). Although, Coulter and Kozub (1984) could not establish a significant correlation between back fat thickness and SC in bulls of similar age to those of the OB group.

Correlation coefficients calculated between SC and testis traits such as testis weight and testis volume were high (Table 9.4). This is consistent with previous reports that SC is an accurate predictor of testicular size (Toelle and Robinson, 1985, Gabor *et al.,* 1995). The high correlation coefficients between SC and testis traits when scrotal fat is excluded indicate their close relationship even though the degree of finish carried by the bulls that commenced HE feeding at different ages was slightly different. The use of SC was superior in predicting testis traits such as testis weight and testis volume compared to either age ($r = 0.11$) or body weight ($r = 0.14$).

Fat deposits within the scrotum and scrotal tissue clearly influenced the SC in both the YB and OB groups. The relationship between SC and scrotal fat ($r = 0.85$, Table 9.4) was highly significant ($p < 0.001$) in the YB group. In accordance with the foregoing, arguments relating to fat deposition in the scrotum when HE feeding is delayed to a later age, the correlation between scrotal fat and scrotal circumference was low in such animals (Table 9.4). Mwansa and Makarechian (1991) noted that the rate of fat deposition would significantly influence the rate of increase in scrotal circumference in the bull. Scrotal fat influenced ($p < 0.05$) scrotal skin weight in the YB and OB group, probably due to the deposition of subcutaneous fat as a result of the HE diet. Scrotal fat deposits were also positively correlated with scrotal skin thickness in both age groups of bulls. Both groups of bulls had a high correlation coefficient between scrotal fat and scrotal skin thickness (YB; $r = 0.68$, $p = 0.003$, OB; $r = 0.65$, $p = 0.004$). This may also be ascribed to increased amounts of subcutaneous fat that are associated with the feeding of HE diets.

By contrast, Coulter and Kozub (1984) reported a negative correlation between scrotal skin thickness and SC in bulls fed HE diets. This contrasts with what is generally expected, because a greater scrotal skin thickness would generally be expected to equate with increased scrotal diameter and inflate SC measurements. However, they did state that the relationship found between SC and scrotal skin thickness warranted further investigation.

Seminal traits in both bull age groups were varied in this study and no fixed trend could be established between SC and seminal traits. Body condition score and CDP did however seem to affect semen traits negatively. A significant ($p < 0.05$) negative relationship was observed between CFG ($r = -0.48$), BCS ($r = -0.53$) and percentage linear motility of semen in the OB group.

The results from this study indicate that fertility is compromised when bulls are fed high-energy diets, but the effect on fertility is more pronounced when such HE feeding is initiated at a young age. These results support those reported by Coulter and Kozub (1984), Coulter *et al.* (1987a) and Coulter and Bailey (1988), who established that bulls with better BCS have reduced epididymal sperm reserves, lower sperm motility and more minor and major seminal defects. This is contrary to the statement by Cates (1975) who reported that, regardless of age or breed, the probability of a bull being a satisfactory breeder increases as SC increases, which only seems to apply when bulls are not fed a diet high in energy at a young age.

9.6 CONCLUSION

Results from this study indicate that the age at which young bulls are fed HE affects their future reproductive performance. It is also possible that age purse could account in part for the low semen volumes and high levels of major and minor semen defects observed in this study. It is likely that regardless of whether lower semen quantity and quality is expected in yearling bulls that the pathogenesis of testicular degeneration presented in Table 9.2 indicates that the degenerative effect is on the primary spermatocytes which affect secondary spermatogenesis. This then results in an increased number of sperm defects, ultimately reducing fertility of the bulls. In addition, the high level of damage to the seminiferous epithelium, high rate of vacuolation and tubules devoid of spermatides together with increased levels of collagen fibrosis formation around the tubules indicates that testicular integrity could be permanently compromised. Therefore, feeding young bulls high energy diets will result in improved growth traits, but adversely affect the fertility of these animals. Furthermore, SC is not an accurate predictor of fertility when bulls are fed a high-energy diet. Significantly more fat was deposited within the scrotum and scrotal tissue of bulls fed HE diets at the younger age. These create errors in using SC as a measure of spermatozoa producing capacity. Under these circumstances it would appear that bigger is not necessarily better. It also appears that the effect is greater in younger bulls compared to older bulls.

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CHAPTER 10

IMPLICATIONS AND GENERAL RECOMMENDATIONS

Beef cattle production in Southern Africa is predominantly practised extensively utilising natural pasture. The region is characterised by marked seasonal and annual variations in temperature and rainfall. The resultant effect is variations in parasite burdens, and occurrences of disease. Probably the greatest constraint limiting beef production is the low and variable rainfall experienced in Southern Africa. This is then manifested in large fluctuations in the quantity and quality of available feed. Also, beef cattle production in this environment is essentially under limited or incorrect animal systems, plagued by problems which include high mortalities, low fertility and slow growth rates. Many of the problems experienced by producers are self-induced, due to inefficient selection and management systems. Genetic improvement and increased profitability of beef cattle in this environment should be directed toward identification of the major environmental constraints and those limiting optimal growth and fertility under extensive management conditions.

Cattle breeds developed for beef production under tropical conditions inherently posses both genes for adaptability and production. The results from this study demonstrate that acceptable levels of fertility and growth are achievable from these breeds under the arid sup-tropical conditions of Southern Africa. A spring / summer calving season should be maintained as the main season since calves born in the early summer are lighter, reducing the incidence of dystocia, but out-perform winter-born calves in pre- and post-weaning growth traits. Similarly, calves born to fertile cows are born earlier in the calving season, tend to be lighter at birth and grow faster than calves born to less fertile cows.

The interrelationships among lifetime cow fertility, cow size and pre- and post-weaning calf growth in tropically adapted cattle indicate that cows of higher lifetime fertility are smaller in size and have significantly lighter calves at weaning. The high post-weaning growth rates of the progeny of more fertile cows negate the weight advantage of the calves from the less fertile cows even though the latter weaned calves with higher weights.

Results on the effect of heifer frame size on the subsequent reproductive and pre-weaning performance of Santa Gertrudis cattle clearly indicate that cow frame size influences reproductive and pre-weaning growth performance of Santa Gertrudis cattle, under extensive management conditions in the arid hot and dry climate of Southern Africa. Small and medium frame sizes cows had similar reproductive results and significantly out-performed large framed cows. Small-framed cows were generally more fertile compared to medium and large-framed cows. The results form this study also show that significantly more large framed cows were eliminated from this study as a result of low conception rates. This implies a difference in production efficiency between the different frame sizes. Results from these studies would be purely of academic interest, without demonstrating the impact frame size has on a weaner production system for the producer. A monetary value can be applied to the production efficiency of the different frame size groups based on weaning rate, weaning weight of the calf and the current price paid for weaners (R13.00) in Southern Africa. As first time calvers there was no difference in weaning rate between the different frame sizes. The large frame size animals had the highest income due to their heavier calves which resulted in an advantage of R23718.50 in favour of the large frame over the small frame animals and a mere R3192.80 over the medium frame females. However, as second parity cows the large frame animals suffered the most and were significantly out performed by the small and medium frame cows. The small frame cows had an income advantage of R137073.95 over the large frame animals and a marginal income of R930.93 over the medium frame animals. From the third parity a small number (approximately 40%) of the large frame cows were able to calve regularly and cope with the interaction between frame size and the nutritional environment once they had reached maturity. Weaning rates were similar and although the large frame cows produced higher weaning weights, they were not able to recuperate the losses incurred as second calvers. The medium frame cows had better production results than the small framed cows, because they grew faster and weaned heavier calves. Income from medium frame cows was R155858.58 over large frame and R33123.89 over small frame animals for the duration of this study. Although, the calculations ignore the maintenance costs for cows of different frame size, it is abundantly clear that when selecting cattle for the arid hot and dry climatic regions of Southern Africa under extensive management conditions, the recommended cow frame size should be a medium framed animal. These animals have similar levels of fertility compared to small framed cows, but with similar or even better growth performances than large framed animals.

Natural host resistance to ticks could be the single most important factor affecting the economics of tick control. This is because it is a low cost, permanent solution requiring no extra resources and incurring no additional cost to generate a given amount of product. In order to achieve this strategy, the identification of traits that could limit the concentration of ticks on beef cattle, under natural grazing conditions, should be considered. Animals that are best adapted to tropical environments are able to carry a lower heat load. These are also the animals that have lower tick concentrations. Management strategies should give special attention to younger animals as they are the animals most prone to tick infestations and strategic dipping programmes using *acaricides* should be applied to control a tick population on young animals, but care should be taken not to disturb the desired development of immunity and tick resistance.

Pregnancy in the cow, results only following successful mating and therefore, the reproductive efficiency of bulls and cows both contribute to the expressed reproductive performance of the cow herd. As most of the beef bulls are used for natural service in Southern Africa, the environment and management practises often affect bull fertility. Nutrition is an environmental effect that may have pronounced affects on bull fertility. Beef cattle producers and performance testing schemes utilise high dietary energy levels to test and finish off bulls, which could reduce the reproductive potential of young bulls.

The use of SC as a predictor of bull fertility is questionable under these conditions.

The results from this study on the relationship between growth parameters, scrotal circumference and sheath area in Santa Gertrudis bulls indicate that the pre-weaning stage is a critical period for testicular development, because bulls with inferior testicular development at a young age showed an increase in SC with both age and body weight, while bulls with superior development at a young age continued to maintain that advantage at a later stage of development. Therefore, the probability of finding bulls with smaller than average testis among bulls selected at weaning would be smaller than in bulls selected for growth rate in a feedlot test.

Focusing attention on a characteristic which is important in the selection of Santa Gertrudis and allied breeds namely sheath area, it is clear that post weaning growth does not necessary account for a significant amount of variation in sheath area. This suggests that selection could be effective in reducing sheath area, but it could be antagonistic with pre- and post- weaning growth. However, the low order of the correlation 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.

The effect of high-energy diets on the reproductive performance of yearling bulls suggest that it is practical to select for larger SC in young beef bulls to improve fertility, provided that they are not fed high-energy diets. Feeding of

HE diet at what seems to be a critical stage of development in young bulls markedly increases the fat deposition in the scrotum. Not only does this reduce the predictive value of the SC as an indicator of potential spermatozoa production, but also reduces the fertilizing capacity of the ejaculate.

Due to escalating costs beef cattle producers can no longer afford the luxury of inefficiency due to escalating input costs. In order to be more efficient beef cattle producers should have a sound knowledge of the fundamentals of the environment in which the animal is to produce its inherent biology and associated genetic potential together with their interactions, understand market trends and produce a quality product if they are to remain financially viable.