FACTORS AFFECTING THE PRODUCTION AND REPRODUCTION PERFORMANCE OF TROPICALLY ADAPTED BEEF CATTLE IN SOUTHERN AFRICA

by

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SUMMARY

In the first study, non-genetic influences on pre- and post-weaning growth traits of a tropically adapted beef breed in the arid sub-tropical environment of Southern Africa were investigated. Production data of Santa Gertrudis cattle for a ten-year period were analysed. The herds were managed extensively under harsh arid environmental conditions in the northern thornveld region of Namibia. The cattle were divided into summer and winter breeding seasons, which were limited to 90 days for each group. The effect of sex, herd, season, calf birth year and cow parity group on birth weight, pre-weaning average daily gain, weaning weight, yearling weight, eighteen month weight and post-weaning growth rate were analysed. Sex was a highly significant (p < 0.001) source of variation for birth weight, weaning weight, 12 month weight, 18 month weight and significantly influenced (p < 0.05) pre and post-weaning weight gain. Bull calves were 3.05, 13.75, 123.37 and 238.99 kg heavier than the heifer calves at birth, weaning, yearling and eighteen months respectively and grew faster by 0.07 kg/day from birth to weaning and 0.65 kg/day from weaning to 12 months of age. The effect of season on birth weight, weaning weight, 18-month weight and pre-weaning growth rate was highly significant (p < 0.001). Calves born in the summer season had a lower birth weight compared to calves born in the winter season. However, the summer season calves were heavier by 17.67 kg at weaning but only by 1.7 kg at 12 months of age. They grew faster by 0.16 kg/day from birth to weaning. Calf birth year significantly influenced (p < 0.001) all traits measured with no fixed trend over time for the traits. Herd effects were highly significant (p < 0.001) for birth weight and 12-month weights and significantly influenced (p < 0.05) weaning weight, 18-month weight and growth rate from weaning to 12 months of age. The effect of cow parity was not significant on birth weight, 12-month weights, 18-month weights and post-weaning growth rates, but was significant (p < 0.05) for weaning weight and pre-weaning growth rates. Sex, herd, season of calving, calf birth year and herd x season x calf birth year significantly influenced growth traits and should be taken into consideration when evaluating the genetic merit of cattle during selection.

The second study was conducted to determine the associations between lifetime cow fertility and cow frame size, also between lifetime cow fertility and pre-weaning as well as post-weaning calf growth in tropically adapted Santa Gertrudis cattle. A total of 2 506 Santa Gertrudis cows were divided according to their average lifetime calving interval (CI) into short calving interval (SCI, < 400 days, n = 914 cows) and long calving interval (LCI, > 400 days, n = 1 592 cows) groups. Calves were weighed at weaning at approximately 7 months of age. Hip height of cows and pre-weaning gain of calves of the SCI cows (135 cm and 1.01 kg/day) were significantly (p < 0.05) lower than those of the LCI cows (141 cm and 1.25 kg/day). Calves from SCI cows were born significantly earlier in the calving season than calves from LCI cows as measured by age at weaning (221 versus 189 days). As a result of

compensatory growth there was no significant difference for yearling weight between progeny of SCI and LCI cows (348 kg versus 349 kg). It is concluded that SCI cows are smaller in size, with significantly lighter calves at weaning. A negative correlation exists between fertility and pre-weaning calf growth. High post-weaning calf growth is compatible with high cow fertility.

In the third study, the effects of heifer frame size (FS) on their subsequent performance and the pre-weaning growth of their calves were evaluated using records collected from 1989 to 1998 from the Waterburg Estates at Otjiwarongo, Namibia. Based on hip height at 18 months of age, heifers were assigned to three different frame size (FS) groups: small (< 124 cm), medium (125 to 135 cm), or large (>136 cm). Calving rate (CR), calving date (CD), calf survival rate (CSR), reproductive efficiency (SANDEX), weaning rate (WR), birth weight (BW), weaning weight (WWT), pre-weaning ADG (P-ADG), and kilograms of calf produced per cow bred (KCB) were collected from first –(n = 830), second (n = 623) and third and greater-parity (n = 571) cows. Frame size of heifers significantly influenced ($p < 0.001$) their calving rate as second-parity cows with small and medium FS cows having higher CR than large FS cows. In spite of heavy culling of cows that had large FS as heifers, calving rates of second parity cows in this category were 41% less than that of second parity cows that had small and medium FS as heifers. In third or greater-parity cows, CR was greater ($p < 0.05$) for small FS than for medium and large FS. CSR was similar for heifers with a small, medium and large FS for the first, second and third and greater parity groups. Weaning rates of large FS (34.2 ± 11.27), second-parity cows were less ($p < 0.001$) than those of small (82.9 ± 5.58) and medium (79.0 ± 4.67) FS animals. Among all parity groups, BW of calves born to large FS were significantly higher ($p < 0.05$) than those of small and medium FS cows. Calves weaned by small FS animals as first parity cows, had lower ($p < 0.05$) WWT than those weaned by medium and larger FS, but large FS weaned heavier calves ($p < 0.05$) than small and medium FS in the third and greater-parity group. In first parity cows, calves of large FS had greater P-ADG ($p < 0.05$) than those from small FS, but in second parity cows the calves from medium FS ($p < 0.05$) out performed those of small and large FS, while calves from third and greater parity cows of medium and larger FS had greater ($p < 0.05$) P-ADG than cows with a small FS. Male calves were heavier ($p < 0.05$) at birth, at weaning and grew faster (P-ADG) than their female counterparts. KCB was similar among small and medium FS cows, but both tended to be greater ($p < 0.05$) than KCB of large FS cows and as second parity cows the small and medium FS cows had an even greater ($p < 0.001$) advantage over the large FS animals. Small and medium FS females calved earlier, and had greater calving rates and weaning rates, as well as greater kilogram of calf produced per cow exposed than the large FS females. The performance (fertility and the growth performance of their calves to weaning) traits of the large FS were generally similar to those of smaller cows in the third and greater parity group. The reproductive efficiency (SANDEX) of large FS at first, second, third and greater parity were lower ($p < 0.001$) compared to the small and medium FS, due to the later calving dates. Therefore, selecting cattle for the hot and dry climatic regions of Southern Africa, under extensive management conditions and with limited supplementary feeding, the recommended cow frame size should be a medium frame. These animals have similar levels of fertility

compared to small framed cows, but with similar or even better growth performances than large framed cows.

In the fourth study, the objective was to determine the effect of traits such as age, sex, body weight, body length and height, body condition score (BCS), coat score (CS), skin thickness and average skin surface temperature on tick burdens of a tropically adapted beef breed. Bonsmara cattle (n= 143) were used to measure visible tick counts, body condition score, coat score, skin thickness, body height and length, body weight, body surface temperature, gender and inter calving period. Measurements were taken for a period of eight months from April to December. All animals were managed extensively on natural and cultivated pastures near George in the Southern Cape. Female animals had significantly ($p<0.05$) greater tick infestation (37.9±2.7) compared to male animals (16.5±1.2). Age was a significant factor ($p<0.001$) with the younger animals below two years having (46.4±5.26) more ticks than those of two years and older (20.1±2.44). A significant negative correlation ($r = -0.29$; $p<0.001$) was reported between the infestation of ticks on the animals and the age of the animal. Animals with an average body weight below 250kg had 42% ($p<0.05$) more ticks compared to animals with a body weight above 250kg. Age of the animal and weight were highly correlated ($r = 0.70$; $p<0.001$), while the correlation between the number of ticks per cow and the mean weight was negatively correlated ($r = -0.37$; $p<0.001$). Skin surface temperature significantly influenced tick infestation on the animals ($p<0.001$). The degree of infestation increased as body surface temperature exceeded 30º Celsius. Coat score, skin thickness, body condition score and inter calving period did not significantly influence tick infestation on the animals. The infestation of ticks on the animals was significantly influenced by body height ($p<0.019$) and body length ($p<0.001$). Animals smaller than a 130cm in height had a significantly ($p<0.05$) greater tick infestation (36.5±5.0) compared to animals taller than 130cm (21.2±1.5). This trend was also observed for body length. Animals with a body length shorter than 145cm had a greater ($p<0.05$) average tick infestation of 41.3±4.5 compared to 23.2±1.3 for animals longer than 145cm, indicating a 44% greater tick infestation for the shorter animals. The selection of cattle for adaptability and thus increased production under tropical conditions, through resistance to ticks should be for animals of medium frame sizes having smoother coats that are able to dissipate heat effectively.

In the fifth study, the relationship between growth parameters, scrotal circumference and sheath area in tropically adapted beef bulls was investigated. 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 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 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, giving careful attention to sheath area in bulls, selected as yearlings is possible without necessarily sacrificing growth performance.

In the sixth study, associations among growth and quantitative testicular traits of tropically adapted yearling bulls fed different dietary energy levels were investigated. High energy (HE), medium energy (ME) and low energy (LE) diets were fed to young Bonsmara bulls post-weaning and the subsequent effects on scrotal circumference (SC), average daily gain over an 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 terms of 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 negative association was observed 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. The present results suggest that feeding HE diets to young bulls influenced their testicular development and reduced their reproductive potential.

In the seventh and last study, the relationship between scrotal circumference, quantitative testicular traits and growth performance in tropically adapted yearling beef bulls differing in age was investigated. 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 ± 11.68g; 576.6 ± 25.17g and 4.5 ± 0.15mm) compared to that of the older group (1010.15 ± 50.10g; 255.9 ± 13.55g and 4.0 ± 0.13mm). The weight of the epididymal / spermatic cord (WESC) was heavier (p < 0.05) in the older bulls (70.2 ± 3.53g) compared to that of the younger group (47.2 ± 3.17g) 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 ± 102.20g vs OB = 263.5 ± 27.52g). 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.

PREFACE

The purpose of this study was to critically evaluate factors that influence the production and reproduction of beef cattle, managed extensively on natural pasture in the sub-tropical region of Southern Africa. Significant progress was made and valuable information obtained in the fields of beef cattle production science over the past 50 years. Despite moving from subjective measuring methods to more scientific, objective means of measurement, very little progress has been made in terms of the national calving percentage over the past 30 years. Hopefully the study has made a meaningful contribution to emphasize factors which effect production and reproductive performance of beef cattle managed extensively on natural pasture and in the process challenge existing practises.

The thesis is divided into three sections: Section A includes a general introduction and three articles that deal with factors affecting production and reproduction in the cow herd, with the focus being on the effect of heifer size and the subsequent productivity of their progeny and on herd productivity. Section B focuses on traits that determine the parasite load in tropically adapted cattle. Section C focuses on factors affecting the fertility and production in bulls. It is attempted through the three sections to contribute significantly to the existing information of beef production science in a scientific and coherent fashion. Due to the structure of the thesis and nature of the study a limited amount of repetition was unavoidable. However, every effort has been made to limit repetition.

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I hereby declare that this thesis submitted for the degree of Doctor of Philosophy is my original work and has not been submitted by me in respect of a degree to any other University, and the views expressed are my own.

G. J. TAYLOR

LIST OF ABBREVIATIONS

AAS	Age at slaughter
ADG	Average daily gain
ADA	Average daily gain per day of age
BSE	Breeding soundness examination
BS temp	Body surface temperature
BW	Birth weight
CD	Calving date
CDP	Carcass dressing percentage
CFG	Carcass fat grade
CI	Calving interval
CLT	Circumference of left testis
cm	Centimetre
cm^3	Cubic Centimetre
CR	Calving rate
CRT	Circumference of right testis
CS	Coat score
CSR	Calf survival rate
DM	Dry matter
ESC	Epididymis and spermatic cord
ESR	Epididymal sperm reserves
FCE	Feed conversion efficiency
FCR	Feed conversion ratio
FS	Frame size

g	Grams
ha	Hectares
HE	High energy
HFG	High fertility group
ICP	Inter calving period
Kg	Kilogram
LCI	Long calving interval
LE	Low energy
LFG	Low fertility group
LSA	Large sheath area
LSG	Large sheath group
LSU	Large stock unit
LW	Live weight
max	Maximum
ME	Medium energy
MFG	Medium fertility group
mg	Milligrams
min	Minimum
MJ	Mega joules
mm	Millimetres
n	number
OB	Older bull group
P-ADG	Pre-weaning average daily gain
PEC	Production efficiency per group
PEG	Production efficiency per cow group

PIT	Percentage inactive tubuli
PLS	Percentage live sperm
PLSM	Percentage linear sperm motility
PMSD	Percentage major sperm defects
PMISD	Percentage minor sperm defects
PPG	Kilograms of calf produced per cow bred
PTW	Paired testis weight
R	Rands
SCI	Short calving interval
SC	Scrotal circumference
Scon	Sperm concentration
Scount	Sperm count
SEM	Standard error of the mean
SF	Scrotal fat
SMM	Sperm mass movement
SSA	Small sheath area
SSG	Small sheath group
SST	Scrotal skin thickness
SSW	Scrotal skin weight
SW	Scrotal weight
TTV	Total testicular circumference
VESC	Volume of the epididymal spermatic cord
VS	Versus
YB	Young bull group
WCC	Weight of cold carcass

WCW   Weight of warm carcass

WESC   Weight of the epididymal spermatic cord

WLT   Weight of left testis

WR   Weaning rate

WRT   Weight of right testis

WWT   Weaning weight

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SECTION A

CHAPTER 1

1.1   GENERAL INTRODUCTION

Beef cattle production in Southern Africa is predominantly an extensive system, being based on the utilisation of mainly natural pastures. Smit (1999) noted that natural pasture remains the cheapest source of forage for cattle production, but that the economic viability of cattle farming is coming under pressure due to ever increasing input costs. Furthermore, cattle production in the subtropics is not only faced with climatic and nutritional stresses, but is also subjected to managerial and disease limitations. Thus, susceptibility to these stressors accounts for large differences in growth rate, fertility and mortalities between and within breeds. Therefore, breeds that are able to adapt to these stressors can be expected to be more profitable (Van Zyl *et al.,* 1993).

During the past thirty years, despite a weaner production system having been proven to be less profitable than the sale of more mature cattle, this is still the system applied most widely in South Africa by beef producers. A report in the Agri Review (1995) noted that beef cattle producers were comparatively worse off in 1994 than in 1988 as a result of increased input costs, while producer prices remained fairly constant. These concerns are as relevant today (Cousins, 2004) as they were 10 years ago. The reason is that beef prices show a recurring long-term cycle with high prices being repeated every

five to ten years. Prices then remain fairly constant over the intervening period while input costs escalate. Thus, it is imperative that producers strive to be more efficient. However, this does not seem to be taking place, as the national calving average remains at between 50 and 60% (Harwin *et al.,* 1967, Meaker 1984, MacGregor, 1997, Parkinson, 2003). It is therefore clear that past and current selection and management practices have not been successful in increasing the efficiency of weaner production systems. It seems fair to speculate that in order to make cow-calf operations more efficient and profitable, without drastically increasing input costs, cattle producers will have to improve the reproductive and production efficiencies of their herds. Bellows and Short (1994) observed that the greatest production loss results from cows not being pregnant at the end of the breeding season. The long term, improvement in reproduction can come via selecting animals that are adapted to a particular environment, but improvements in the environment should not be ignored. Simply improving the management system can rapidly improve the reproduction rate of a herd. This is worthy of note since it is generally accepted that reproductive performance is the most important economic trait in a beef cow-calf herd and far exceeds the impact of improved growth rates. It is important therefore, that aspects impacting on fertility receive the major research emphasis. Aspects investigated were non-genetic factors (environmental) influencing production, fertility level and heifer frame size and their subsequent relationship to the production traits of their calves.

Adaptability is the basis for successful and efficient extensive beef cattle production in the sub-tropics. A certain minimum level is required to achieve

adequate reproduction and production levels within specific environmental conditions. In this regard the control of ticks in tropical areas is significant. This study investigates factors, which influence reproduction and production performance of beef cattle under extensive management conditions in the arid sub-tropics of Southern Africa. Control of ticks is an important, time consuming and costly aspect of cattle production in tropical areas. An attempt was thus made to identify traits that influence tick burdens on cattle. Animals that have low tick burdens are probably adapted to the environment in which they occur. The motivation was that selection of animals adapted to the stressors of the tropics could lower input costs, decrease body maintenance costs, improve body condition and ultimately improve reproductive performance. This should improve overall herd efficiency.

Furthermore, the impact the bull has on herd fertility is often underestimated and poor conception rates are generally considered to be female orientated. However, certain management decisions could adversely impact on bull fertility and equally contribute to lowered herd fertility. In this context the role played by herd sires should also receive due cognisance and attention not focussed only on increasing growth rates through the ability of such sires to impart their genetic potential to their progeny.

Following this introduction the thesis is structured as follows: In Chapter 2 the non-genetic influences on pre- and post-weaning growth traits of a tropically adapted beef breed in the arid sub-tropical environment of Southern Africa are addressed. The interrelationship among lifetime cow fertility, cow size, pre-

weaning and post-weaning calf growth in Santa Gertrudis cattle is discussed in Chapter 3. Chapter 4 deals with the effect of heifer frame size on their subsequent reproductive performance and on the pre-weaning performance of their calves. These three chapters deal with factors affecting the production of the cow herd. Section B, Chapter 5 addresses the tick burdens of tropically adapted beef cattle as influenced by selected physical and production traits. The last section (section C) includes Chapter 6 which introduces this section, is followed by Chapter 7 focussing on the relationship between growth parameters, scrotal circumference and sheath area in tropically adapted beef bulls. Chapter 8 evaluates the association among growth and quantitative testicular traits of tropically adapted yearling bulls fed different dietary energy levels. Followed by Chapter 9, the relationship between scrotal circumference, quantitative testicular traits and growth performance in tropically adapted yearling beef bulls differing in age is addressed. Finally general implications and recommendations addressing beef cattle production in a scientific manner are presented in Chapter 10.

Although every effort were made to limit repetition, the structure and layout of the thesis having being prepared in a publication format has made this unavoidable.

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CHAPTER 2

NON-GENETIC INFLUENCES ON PRE- AND POST-WEANING GROWTH TRAITS OF A TROPICALLY ADAPTED BEEF BREED IN THE ARID SUB-TROPICAL ENVIRONMENT OF SOUTHERN AFRICA

2.1   ABSTRACT

Production data of Santa Gertrudis cattle for a ten-year period were analyzed. The herds were managed extensively under harsh arid environmental conditions in the northern thornveld region of Namibia. The cattle were divided into summer and winter breeding seasons, which were limited to 90 days for each group. The effect of sex, herd, season, calf birth year and cow parity group on birth weight, pre-weaning average daily gain, weaning weight, yearling weight, eighteen month weight and post-weaning growth rate were analyzed. Sex was a highly significant ($p < 0.001$) source of variation for birth weight, weaning weight, 12 month weight, 18 month weight and significantly influenced ($p < 0.05$) pre- and post-weaning weight gain. Male calves were 3.05, 13.75, 123.37 and 238.99 kg heavier than the female calves at birth, weaning, yearling and eighteen months respectively and grew faster by 0.07 kg/day from birth to weaning and 0.65 kg/day from weaning to 12 months of age. The effect of season on birth weight, weaning weight, 18-month weight and pre-weaning growth rate was highly significant ($p < 0.001$). Calves born in the summer season had a lower birth weight compared to calves born in the winter season. However, the summer season calves were heavier by 17.67 kg at weaning but only by 1.7 kg at 12 months. They grew faster by 0.16

kg/day from birth to weaning. Calf birth year significantly influenced (p < 0.001) all traits measured with no fixed trend over time for the traits. Herd effects were highly significant (p < 0.001) for birth weight and 12-month weights and significantly influenced (p < 0.05) weaning weight, 18-month weight and growth rate from weaning to 12 months. The effect of cow parity was not significant on birth weight, 12-month weights, 18-month weights and post-weaning growth rates, but was significant (p < 0.05) for weaning weight and pre-weaning growth rates. Sex, herd, season of calving, calf birth year and herd x season x calf birth year significantly influenced growth traits and should be taken into consideration when selecting cattle.

2.2 INTRODUCTION

It is generally recognised that poor reproductive and reduced growth performance are the major factors limiting cattle production in the tropics (Jones and Hennessy, 2000). The constraints placed on production traits are predominately environmentally imposed (Duarte-Ortuno *et al.,* 1988, Howden *et al.,* 1999). Under reasonable management conditions in the subtropics, crossbreeding Zebu cattle with *Bos taurus* breeds can increase production by improving reproductive performance, together with pre- and post-weaning growth (Koger 1973, Koger 1980, Gregory *et al.,* 1999). However, with cross-breeding comes the dilution of genetic resistance to tropical diseases and the need for improved feeding and management is increased. Moreover, cross-breeding may pose a threat to long-term genetic conservation of local genetic resources (Kurwijila 2005).

The importation of Santa Gertrudis cattle by the South African government in 1956 from King Ranch, Texas, offered the seed stock producers an attractive alternative to the British breeds less adapted to tropical climates. Seed stock producers were afforded the opportunity to capitalise on a cattle breed with favourable characteristics in terms of production and adaptability in hot climates. Furthermore, it is generally acknowledged that beef cattle operations in Southern Africa are practised mainly on natural pasture (Meaker, 1984). However, information on the production efficiency norms for cow herds under arid environmental conditions in Southern Africa is limited. Published information on the performance of the Santa Gertrudis cattle in the Southern African sub-tropics is also decidedly scarce. The objective of this study was to provide information on the production characteristics of Santa Gertrudis cattle under extensive grazing and management conditions in the arid sub-tropical environment of Southern Africa.

2.3   MATERIAL AND METHODS

Data were collected from 1979 to 1998 from Santa Gertrudis herds on a ranch in the north-eastern part of Namibia where single sire mating was practised. The calving and progeny data recorded were also checked with the records kept by the South African Santa Gertrudis Cattle Breeder Society. Information from record cards on cattle then present and those no longer in the herd was extracted for sex, date of birth and weaning, weights at birth, weaning, 12 and 18 months. Data were edited for errors and outliers (weights of animals differing greatly from the norm that were either excessively light or heavy for a specific age group). Calf weights at weaning, 12 and 18 months were

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computed from the weighing dates closest to the actual dates. All records where the calf or dam identification number was missing were deleted.

The ranch is situated 17° east, 20.5° south and 1 500 m above sea level, comprising an area of 55 000 ha, of which 42 000 ha was available for commercial cattle ranching. The herd was kept under extensive management, with a limited salt-phosphate lick. Cattle were grazed on natural pastures, which can be classified as "thorn bush savannah". The vegetation in the area includes woody species such as *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca* and the major grass species, were *Eragrostis rigidior, Panicum maximum* and *Digitaria eriantha*. A short duration (less than 3 weeks) and long rest (5 – 8 month) rotational grazing system was practised.

Average monthly temperatures ranged from a maximum of 32°C in January to a maximum of 14.5°C in July. The soils are predominantly sand and loam, with scattered areas comprising acid granite. The rain falls predominantly between October and March, with 80% of the yearly rainfall occurring in this period. The rainfall averaged 485 mm per year, but from 1979 – 1998, the area experienced drought conditions and received less than 403 mm per year.

A 90-day breeding season was used with the summer breeding season starting mid-January and ending mid-April and mid July to mid August for the winter breeding season. All bulls allocated cows for breeding within each herd were sheath washed for vibriosis *(Compylobacter foetus)* and trichomoniases *(Trichomonas foetus)* infection using a 0.9% physiological phosphate buffered

saline solution before being fertility tested. Three weeks before the breeding season commenced, semen was collected by means of electro-ejaculation. The breeding soundness examination endorsed by the society of Theriogenology (Ball *et al.,* 1983) served as the guideline for the evaluation of spermatozoa. Cows were selected on age (based on number of permanent incisors and on the state of teeth wear), and fertility. A policy of culling females that did not calve for two consecutive breeding seasons was consistently followed. Weaning weights, weaning rates and herd retention of calves, were also used in the selection process. Occasional culling for poor temperament and uterine prolapses also took place. Cow fertility was coded as high for cows with an average calving interval of less than 400 days (HFG), medium for cows with a calving interval of between 401 and 467 days (MFG) and low for cows with a calving interval of more than 467 days (LFG). Weighing of calves took place at weaning, which was done between 7 – 9 months depending on the season (Calves were weaned at approximately 7 months of age in years receiving lower rainfalls and closer to 9 months in years with higher rainfall).

For each of the summer and winter breeding seasons the weaned heifer calves were combined into one herd and culling was for low weight-for-age, lack of sexual development and structural faults (e.g.: devils grip, lack of femininity, lack of sexual development in the form of vulva and udder development, feet and leg faults, over or undershot jaws). Once a second selection process was completed at approximately 20 months of age heifers were allocated to a breeding herd. Although both herds were managed

extensively on natural pastures, heifers which performed above average for growth and development were selected for herd A, as this was considered to be the "first cut" single sire herd. Heifers that were below the herd average for growth and development were considered "second cut" heifers and allocated to herd B. The number of heifers allocated to herds A and B varied from year to year depending on the size of the calf crop and culling intensity of the different herds before bulling commenced at this time. Culling was once again on the basis of low weight-for-age, lack of sexual development and structural faults. The average culling rate was approximately 10% for heifers selected at 20 months of age prior to bulling. The different herds were kept in separate, but adjacent camps and to reduce possible camp effects, camps were not allocated in blocks but were randomly and evenly dispersed over the whole study area. Cow-herds were kept in close proximity to each other as far as was practically possible and care was taken not to allow the stocking rate to exceed 15 ha/LSU.

Bull calves were not castrated at weaning and were all weaned into one herd, where they remained on natural pasture until they were about 2 years old. Such two-year old bulls were then selected each year on high weight-for-age and large scrotal circumference (>32 cm). Bulls with large pendulous sheaths were also culled and selection was also for good temperament and sleek hair coat. Less than 10% of the annual bull crop was kept for own use or sold to other breeders. Bulls not selected were slaughtered.

The data were analysed using a mixed linear model, with sire fitted as a random effect and sex, herd (H), season (S), calf birth year (C), calving status based on the number of calves produced (parity group) and the C x S x H interaction fitted as fixed effects. Fertility level represented as inter-calving period was fitted as a co-variant and ages at weaning, 12 months and 18 months fitted as linear co-variants on weaning, yearling, and eighteen month weight, respectively. The model used for each trait was presented by:

$$Y_{hijklmno} = \mu + P_h + G_i + S_j + H_k + D_l + C_m + R_n + (C \times S \times H)_{jkm} + b(x_{hijklmno} - \bar{X}) + e_{hijklmno},$$

where $Y_{hijklmno}$ = growth trait (birth weight, weaning weight, average daily gain from birth to weaning, twelve month weight, average daily gain from weaning to twelve month weight, eighteen month weight and average daily gain from twelve months to eighteen months) for the oth calf of sex i in the nth fertility level from the hth sire, born by cow of the lth parity group in the jth season and within the mth year and reared in the kth herd,

μ = overall mean,

P_h = random effect of hth sire,

G_i = fixed effect of the ith sex (i = 1, 2),

S_j = fixed effect of the jth season of calving (j = 1, 2),

H_k = fixed effect of the kth herd (k = 1, 2)

D_l = fixed effect of the lth calving status or parity group (l = 1, …10+),

C_m = fixed effect of the mth calf birth year (m = 86, … 99),

R_n = fixed effect of the nth fertility (n = 1 (HFG), 2 (MFG), 3 (LFG)),

$(C \times S \times H)_{jkm}$ = herd x season x calf birth year interaction,

b = linear regression of calf weight (weaning weight, yearling weight or eighteen month weight) on age at weaning, at yearling and at eighteen months respectively,

$x_{hijklmno}$ = exact age of oth calf (days) at weaning, yearling or eighteen months,

X = mean age at weaning, yearling or eighteen months and

$e_{hijklmno}$ = random error, assumed to be normally and independently distributed with a zero mean and a variance of σ^2.

The data were analysed using the General Linear Models Procedures of the statistical analysis system (SAS, 1995). Previous lactation status of the dam had no significant effect on growth traits pre-weaning or post-weaning and was not included. Effects included in the final analysis were those found to be significant from a preliminary analysis. The program adjusted for significant fixed effects and the least square means and standard errors (SE) for each growth trait are presented.

2.4   RESULTS AND DISCUSSION

The least squares means (LSM) and standard errors (SE) for the fixed effects and co-variables used to determine pre-weaning and post-weaning growth traits in Santa Gertrudis cattle are presented in Tables 2.1 and 2.2 respectively. The overall least squares means for live weight from birth to 18-month weight are in agreement with those reported by Cartwright *et al.* (1964) for Brahman x Hereford cattle, Hailu and Thorvaldur (1986) for Boran cattle and Koch *et al.* (1994) and Newman *et al.* (2002) for Santa Gertrudis cattle.

Sex was a highly significant ($p < 0.001$) source of variation for weights at birth, weaning, 12 months and 18 months and significantly influenced pre- and post-weaning weight gain. The males were 8.7% heavier than their female counterparts at birth. They further outperformed the females for all traits measured pre-weaning, with a similar trend reported for post-weaning traits. Interpretation of post weaning results for male and female contemporary groups is complicated by the fact that male and female calves were managed as separate groups post-weaning. They were however, grazed in close proximity to each other and subjected to similar management practises. On average, male calves were 6.1%, 39.8% and 68.2% heavier than females at weaning, 12 months and 18 months of age and grew faster by 0.07 kg and 0.60 kg pre- and post weaning respectively. The significant effect of sex reported in this study is in agreement with similar results obtained for pre-weaning growth traits by Lesmeister *et al.* (1973), Reynolds *et al.* (1982), Rege and Moyo (1993), MacGregor (1997) and Tomo *et al.* (1999) who found male calves were usually heavier than female calves at birth and at weaning. Objective post-weaning comparisons are limited, but Ebangi (2000) reported post-weaning growth traits in favour of male animals and Eriksson *et al.* (2002) observed that male animals grew faster than female animals post weaning. Ebangi (2000) ascribed the difference reported between male and female animals to mainly differences in their endocrinological functions. In the present study a combination of endocrinological functions and the increased selection pressure on males than female calves may account for the findings.

Table 2.1 : Least squares means (±SEM) for weight (kg) and average daily weight gain (kg) from birth to weaning of Santa Gertrudis Cattle.

Fixed effects	No.	Birth (kg)	No.	Weaning (kg)	No.	Birth – weaning (kg)
Overall Herd	1057	**	2506	*	888	*NS*
A	373	34.1 (0.04)	1233	247.7 (0.68)	297	1.0 (0.01)
B	684	38.2 (0.17)	1273	254.7 (0.68)	591	1.0 (0.01)
Sex		**		**		*
Males	574	38.2 (0.15)	1271	237.2 (0.91)	468	1.06 (0.01)
Females	483	35.1 (0.14)	1235	223.4 (0.81)	420	0.99 (0.01)
Birth Year		**		**		**
1986	3	34.0 (0.01)	62	231.0 (0.89)	1	0.96 (0.01)
1987	12	36.9 (0.15)	96	238.3 (0.74)	1	1.21 (0.01)
1988	53	37.5 (0.15)	151	247.0 (0.72)	51	1.12 (0.01)
1989	85	37.6 (0.13)	169	239.3 (0.73)	78	1.04 (0.01)
1990	164	36.5 (0.13)	160	247.1 (0.59)	131	1.04 (0.01)
1991	155	35.8 (0.15)	255	226.2 (0.74)	133	0.99 (0.01)
1992	105	36.0 (0.11)	258	223.1 (1.04)	94	0.98 (0.01)
1993	118	37.3 (0.17)	169	247.1 (0.54)	109	1.10 (0.01)
1994	138	36.1 (0.15)	392	214.5 (0.87)	126	1.05 (0.01)
1995	106	36.6 (0.15)	239	226.6 (0.97)	95	0.97 (0.01)
1996	55	38.1 (0.20)	266	226.4 (0.93)	45	1.06 (0.01)
1997	37	40.1 (0.17)	226	229.0 (0.73)	24	0.97 (0.01)
1998	22	37.9 (0.14)	55	247.3 (0.56)	1	0.92 (0.01)

Fertility Level		NS		NS		NS
High	469	36.7 (0.16)	914	239.1 (0.87)	391	1.01 (0.01)
Medium	418	36.8 (0.14)	1032	227.6 (0.89)	352	1.03 (0.01)
Low	170	37.0 (0.15)	560	221.4 (0.80)	145	1.04 (0.01)
Calving Status		NS		*		*
1			4	225.0 (0.001)		
2	269	36.2 (0.14)	689	230.8 (0.91)	220	1.05 (0.01)
3	223	37.0 (0.17)	530	228.4 (0.87)	185	1.02 (0.01)
4	189	36.8 (0.14)	423	229.3 (0.79)	155	1.02 (0.01)
5	136	37.2 (0.15)	322	232.4 (0.86)	120	1.03 (0.01)
6	93	36.7 (0.14)	211	230.2 (0.92)	83	1.01 (0.01)
7	57	37.5 (0.16)	142	232.0 (0.81)	50	1.03 (0.01)
8	33	36.7 (0.18)	82	233.1 (0.98)	29	1.04 (0.01)
9	27	37.6 (0.20)	43	242.8 (0.84)	22	1.05 (0.01)
10+	30	36.8 (0.12)	38	220.2 (0.78)	24	0.92 (0.01)
Season		**		**		**
Summer	825	35.1 (0.12)	1904	239.4 (0.84)	692	1.04 (0.01)
Winter	232	37.1 (0.10)	602	221.7 (0.83)	196	0.88 (0.01)

[*]Means with a different superscript letter within a column and item differ ($p < 0.05$).

[**]Means with a different superscript letter within a column and item differ ($p < 0.001$).

Table 2.2 : Least squares means (±SEM) for weight (kg) and average daily weight gain (kg) from 12 – 18 month of age of Santa Gertrudis cattle.

Fixed effects	No.	12 Months	No.	Wean – 12 Month	No.	18 Months	No.	Wean – 18 Month
Overall Herd	1055	**	991	*	366	*	319	*NS*
A	589	374.5 (2.62)	536	0.79 (0.01)	141	418.3 (5.19)	118	0.53 (0.02)
B	466	327.0 (1.76)	455	0.50 (0.01)	225	427.3 (3.64)	201	0.51 (0.01)
Sex		**		*		**		*
Males	379	432.6 (1.79)	354	1.08 (0.01)	29	589.1 (3.42)	29	0.95 (0.01)
Females	676	309.2 (1.25)	637	0.42 (0.01)	337	350.1 (3.72)	290	0.41 (0.01)
Birth Year		**		**		**		**
1985	17	433.6 (2.79)	4	1.42 (0.01)	2	429.0 (0.96)		
1986	47	412.8 (2.88)	32	0.98 (0.01)	1	343.0 (0.01)	1	0.42 (0.01)
1987	40	383.8 (2.43)	39	0.85 (0.02)	21	331.7 (1.52)	20	0.33 (0.01)
1988	72	374.0 (2.25)	72	0.76 (0.01)	57	385.5 (4.33)	53	0.44 (0.01)
1989	99	351.4 (2.03)	97	0.65 (0.01)	49	425.8 (3.40)	49	0.51 (0.01)
1990	112	365.1 (2.13)	112	0.73 (0.01)	28	454.7 (5.31)	28	0.61 (0.02)
1991	97	360.1 (2.50)	94	0.78 (0.02)	13	467.3 (2.30)	13	0.67 (0.01)
1992	71	342.2 (2.17)	71	0.70 (0.01)	26	309.5 (4.36)	26	0.37 (0.01)
1993	84	360.5 (1.83)	83	0.61 (0.01)	45	339.7 (7.66)	15	0.73 (0.01)
1994	99	327.3 (2.26)	96	0.49 (0.01)	31	361.6 (2.18)	31	0.36 (0.01)
1995	127	327.1 (2.13)	120	0.50 (0.01)	36	302.8 (3.00)	27	0.35 (0.01)
1996	98	325.6 (1.92)	88	0.49 (0.01)	40	342.2 (4.55)	39	0.45 (0.01)
1997	91	358.2 (2.43)	82	0.70 (0.01)	17	361.2 (1.82)	17	0.34 (0.01)
1998	1	286.0 (0.01)	1	0.28 (0.01)				
Fertility Level		*NS*		*		*NS*		*NS*
High	451	348.9 (2.39)	429	0.62 (0.01)	110	384.5 (4.46)	103	0.46 (0.01)
Medium	425	349.9 (2.32)	396	0.64 (0.01)	156	367.7 (5.52)	134	0.48 (0.01)
Low	179	359.9 (2.23)	166	0.70 (0.01)	100	354.2 (4.64)	82	0.42 (0.01)

Calving Status		NS		NS		NS		NS
1	4	404.0 (0.01)	4	1.11 (0.01)				
2	274	362.6 (2.40)	255	0.67 (0.01)	101	362.3 (5.67)	83	0.47 (0.01)
3	224	346.4 (2.22)	203	0.61 (0.01)	90	366.0 (4.60)	81	0.43 (0.01)
4	174	363.6 (2.41)	165	0.71 (0.01)	58	376.8 (4.59)	50	0.45 (0.01)
5	134	356.9 (2.26)	132	0.67 (0.01)	41	360.2 (4.36)	34	0.43 (0.01)
6	85	340.2 (2.19)	84	0.62 (0.01)	30	375.2 (4.76)	27	0.51 (0.01)
7	70	336.3 (2.10)	64	0.57 (0.01)	23	376.9 (4.97)	23	0.47 (0.01)
8	47	350.5 (2.65)	44	0.68 (0.01)	11	396.0 (6.96)	11	0.44 (0.01)
9	20	346.5 (2.55)	17	0.67 (0.01)	6	327.0 (4.99)	4	0.41 (0.01)
10	15	337.2 (2.03)	15	0.68 (0.01)	5	466.8 (3.83)	5	0.67 (0.01)
11	5	324.4 (3.35)	5	0.46 (0.01)	1	353.0 (0.01)	1	0.42 (0.01)
12	2	280.0 (1.22)	2	0.39 (0.01)				
13	1	215.0 (0.01)	1	0.45 (0.01)				
Season		NS		**		NS		NS
Summer	792	368.1 (1.24)	745	0.60 (0.01)	275	414.3 (2.52)	235	0.29 (0.01)
Winter	263	366.4 (1.58)	246	1.15 (0.01)	91	416.2 (2.38)	84	0.34 (0.01)

[*]Means with a different superscript letter within a column and item differ ($p < 0.05$).

[**]Means with a different superscript letter within a column and item differ ($p < 0.001$).

The effect of season on birth, weaning weight, weight gain from birth to weaning and weight gain from weaning to 12 months, was highly significant ($p < 0.001$), but did not affect 12 month and 18 month weights. At birth calves born in winter were 5.5% heavier than those born in summer. This weight difference could possibly be attributed to seasonal variations due to differences in rainfall which in turn affected feed availability. By implication, cows calving down early in the summer season had to endure a period where the pastures are usually mature and of little nutritional value. The last trimester of prenatal calf growth for the summer calving cows occurred during the dry season, usually resulting in weight loss and poor body condition of

pregnant cows due to nutritional stress. It is possible that this nutritional stress is inherently passed to the calf through the prenatal developmental environment. The results of the nutritional stress are reflected in calves with lower birth weights in the summer born calves. The winter born calves consequently have experienced a nutritional stress in the early stages of foetal development. However, in the last trimester of foetal growth when 70% of foetal growth occurs, the pregnant cows have benefited from the more nutritional pastures of the rainy season. These winter calving cows subsequently attained higher body condition scores at weaning compared to those calving in summer. The improved nutritional environment is conducive to foetal development giving the winter-born calves a comparative advantage, which is reflected in a higher ($p < 0.001$) birth weight of the calves. Although the winter calves were heavier at birth, the summer born calves grew significantly ($p < 0.001$) more rapidly and were weaned at a higher weight. Summer calves were almost 8% heavier at weaning compared to winter born calves. It is likely that the summer calves were heavier at weaning because the abundant nutritional grazing during the wet season improved the quality and quantity of milk supplied by the cows. According to Letholu (1983), Dionisio (1989), Bothma (1993) and Erat and Buchanan (2005), 50 to 70% of the variation in weaning weight can be attributed to differences in milk production between cows. The effect of season of birth on live weight and growth of Santa Gertrudis cattle agreed with the findings of De Souza and De Ramos (1995), Nesamvuni (1995) and Plasse *et al.* (1995).

Year of birth significantly influenced birth weight, pre-weaning weight gain, weaning weight, yearling weight, 18-month weight and post-weaning growth. From the results it is evident that no consistent trend over time for maximum average weights and weight gains were observed. The heaviest average birth weight of 40.1 kg was recorded in 1997 while the heaviest average weaning weight and 12 month weights of 276.8 kg and 433.6 kg were recorded in 1985 respectively. The inconsistency in performance from year to year is most probably the result of the erratic environmental conditions experienced in the sub-tropical region of the Southern African continent. The environmental conditions for a specific year are seldom, if ever, repeated. These erratic environmental conditions have a substantial effect on the availability and quality of forage produced in a particular year (Tawonezvi, 1989, Smit *et al.,* 1996). Due to a reduction in herd size during the observation period, the 10 years of drought conditions did not impact negatively on the performance of the Santa Gertrudis cattle. Apparently, sufficient forage on the ranch to sustain the herd during the drought period was allowed for. Hence factors other than rainfall may be responsible for the annual variation in growth of the animals. The drought and fluctuation in environmental conditions necessitated certain management decisions to be made in order to maintain the size of the herds and this could possibly explain the highly significant ($p < 0.001$) herd x calf birth year x season interaction and inconsistency in results obtained in this study. Similar inconsistent results were reported by Anunu and Makarechian (1987) in various crossbred cattle, Rust and Van der Westhuizen (1994) in Simmentaller cattle, and Tomo *et al.* (1999) in Angoni cattle in Mozambique. Improved herd management over the years could also

have attributed to the significant year effect. Changes in the genetic make-up of the animals in the herd may have been a contributing factor responsible for the differences in production of the animals from 1979 to 1998.

Fertility level did not significantly affect birth weight, weaning weight, pre-weaning growth, 12-month weight, and 18-month weight and wean to 18-month weight gain. However, it did have a significant effect on gain from weaning to 12-month. The non-significant effect of fertility group on corrected weaning weight is supported by the findings of Rege and Moyo (1993) and MacGregor (1997). Lishman *et al.* (1984) reported that early calvers produced heavier weaners in two different climatic regions irrespective of feed supplementation of the cows and / or calves. Morris and Cullen (1988) and Garcia Palomo *et al.* (1992) support the results that heavier weaning weights are simply due to the age difference between cows calving early and those calving later in the season. The results from this study are further supported by Marshall *et al.* (1990), who recorded similar results for the different calving groups, finding no significant differences for calf-birth weight or pre-weaning calf ADG and weaning weights. However, weaning weights were 11.51 kg and 17.65 kg heavier for the high fertility group (HFG) over the medium fertility group (MFG) and low fertility group (LFG) in this study respectively (Table 2.1). This is contrary to the findings of Nesamvuni (1995) and Tomo *et al.* (1999). They noted that calves from the least fertile cows were generally the heaviest at weaning since they were mostly those that missed at least one calving season, and were able to recover more rapidly from the stress of reproduction and nursing a calf. Thus, more time to build up body reserves for

subsequent calvings was possible. Fertility level was not a significant source of variation on post weaning growth performance. The HFG calves weighed 10.05 kg and 10.98 kg heavier than the MFG and LFG calves at 12 months (Table 2.2). Rege and Famula (1993) noted a delay in calving date was associated with reduction in yearling weight and average daily gain from weaning to 12 months of age. Meaker *et al.* (1980), Lishman *et al.* (1984) and MacGregor and Swanepoel (1992) reported a favourable relationship between body weight and fertility, while Arije and Wiltbank (1971) and Plasse *et al.* (1995) recorded a positive correlation between age of first oestrus and growth rate. The results from this study are in accordance with MacGregor (1997) and Rege and Moyo (1993), who concluded that earlier calving was associated with higher fertility and would have beneficial effects on growth performance of a herd. Their results are particularly important as their studies were conducted under environmental conditions similar to those found in Southern Africa. The calves of the HFG were 16.8 kg and 30.4 kg lighter than the MFG and LFG at 18 months of age, respectively. Taylor and Swanepoel (2000) found that early and regular calving restricted mature size and could possibly explain the lighter 18-month weight for the HFG as compared to the MFG and LFG categories.

The significant effect of cow reproductive status (parity group) on weight and growth traits observed in this study is similar to the findings by Mabesa (1994) and Tomo *et al.* (1999). Cow reproductive status did not affect birth weight, 12 month, 18 month and post-weaning calf growth. Weaning weight and pre-weaning growth was significantly ($p < 0.05$) reduced by low reproductive

status. Mabesa (1994) and Plasse *et al.* (1995) ascribe the variation in weaning weight and pre-weaning calf growth to variation in milk production. Older cows reaching the end of their productive life tend to show more variation in calf growth, since they produce less milk than younger cows, which tends to retard growth of the sibling progeny.

Herd effect was highly significant ($p < 0.001$) for birth weight and 12-month weight and significantly ($p < 0.05$) affected weaning, 18 month and weaning to 12 month ADG. Heifers allocated to herd A were better adapted to the stresses imposed by the environment, as they were the animals that generally weighing more at 12 and 18 months of age.

2.5   CONCLUSIONS

Sex, herd, calving season, calf birth year and herd x calf birth year x calving season were found to be significant sources of variation for pre and post-weaning growth traits in Santa Gertrudis cattle in Southern Africa. Cow parity group (calving status) influenced weaning weight and pre-weaning growth rates, but had no effect on post weaning growth traits.

Male calves were generally heavier at birth by 8.7% and out grew female calves in production traits measured pre and post-weaning.

Calves born in the summer season were significantly lighter at birth, however they out performed the winter calves in all subsequent growth traits. A summer calving season should be maintained as the main breeding season

as calves born in the summer are lighter, reducing the incidence of dystocia and out perform winter born calves in pre- and post-weaning growth traits.

Calves born to fertile cows (HFG) are born earlier in the calving season, tend to be lighter at birth and grow faster than calves born to less fertile cows.

Production (growth and fertility) results comparable to those obtained for extensive beef production under temperate climatic conditions are achievable in the Southern Africa arid subtropics from cattle breeds that have both the genetic composition for both adaptability and production.

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CHAPTER 3

INTERRELATIONSHIP AMONG LIFETIME COW FERTILITY, COW SIZE, PRE-WEANING AND POST-WEANING CALF GROWTH IN SANTA GERTRUDIS CATTLE

3.1   ABSTRACT

The study was conducted to determine the associations between lifetime cow fertility and cow frame size, also between lifetime cow fertility and pre-weaning as well as post-weaning calf growth in tropically adapted Santa Gertrudis cattle.   A total of 2 506 Santa Gertrudis cows were divided according to their average lifetime calving interval (CI) into short calving interval (SCI, < 400 days, n = 914 cows) and long calving interval (LCI, > 400 days, n = 1 592 cows) groups.   Calves were weighed at weaning at approximately 7 months of age. Hip height of cows and pre-weaning gain of calves of the SCI cows (135 cm and 1.01 kg/day) were significantly (p < 0.05) lower than those of the LCI cows (141 cm and 1.25 kg/day). Calves from SCI cows were born significantly earlier in the calving season than calves from LCI cows as measured by age at weaning (221 vs 189 days). As a result of compensatory growth there was no significant difference for yearling weight between progeny of SCI and LCI cows (348 vs 349 kg). It is concluded that SCI cows are smaller in size, with significantly lighter calves at weaning. A negative correlation exists between fertility and pre-weaning calf growth. Post-weaning calf growth is compatible with high cow fertility.

3.2   INTRODUCTION

Improvement of fertility and growth through selection in beef cattle are becoming increasingly important, as beef production is determined by the reproductive rate, growth rate of calves and weight of culled cows.   It is generally accepted that smaller cows are more fertile under extensive grazing conditions because small body size is an adaptive attribute, but that larger cows produce more milk and, therefore wean heavier calves (Olson, 1994 Mercadante *et al.,* 2000, Minick *et al.,* 2001). However, success of the real practice in different breeds and under different production systems needs to be demonstrated and the effect of lifetime cow fertility on traits such as mature size, weaning weight and post-weaning growth rate need to be evaluated. Calving interval (CI) was used as a measure of reproductive efficiency in this study.   The objective of this paper was to study the associations between lifetime cow fertility and cow frame size, and between lifetime cow fertility and pre-weaning as well as post-weaning calf growth in tropically adapted Santa Gertrudis cattle.

3.3   MATERIAL AND METHODS

Data was obtained from the Santa Gertrudis Cattle Breeders Society of South Africa.   Calving and growth records were analysed from three production systems in the southern African Region over a 12-year period.   These

production systems were managed extensively and the animals had to survive on natural pastures with a summer and winter lick. The breeding seasons were limited to 90 days for heifers and 60 days for the cows. The calves were weaned between 7 and 8 months of age. The bulls were all fertility tested before the breeding season commenced and they were put in with the cows at a 4% ratio. Only cows, which had calved twice, or more were used in this study. Cows were divided into 2 groups according to their average lifetime CI: Those with a CI < 400 days (SCI); and, those cows with a CI > 400 days (LCI). Calving date, weaning weight, 12 month and 18-month weights were recorded. Hip height was also recorded as a measure of cow frame size. Data were analysed using the General Linear Models procedure of Statistical Analysis Systems (SAS 1995). Traits were analysed by the least squares means of variance and the model of analysis included affect due to CI (SCI and LCI), age of dam, previous lactation status, sex of calf, weaning weight, 12 month weight, 18 month weight, hip height of the cows and a regression effect of day of birth.

3.4 RESULTS

The least squares mean for weaning-, 12 month- and 18 month weight of calves, as well as hip height of the cows, for the SCI and LCI groups are presented in Table 2.1.

Cows with higher lifetime fertility (SCI) were significantly smaller and also weaned significantly lighter calves. These cows dropped 78% of their calves during the first half of the calving season, while only 52% of the LCI cows

dropped their calves during the same period, resulting in calves of the SCI group being significantly older (221 days compared to 189 days) at weaning.

Post-weaning growth rate for the progeny from the SCI group of cows was significantly ($p < 0.05$) greater than those progeny from the LCI group, resulting in the actual weight for the two groups not differing significantly ($p < 0.05$) at 12 months of age. Additional compensating growth was evident in the progeny of the SCI cows resulting in significantly ($p < 0.05$) higher 18 month weights in favour of the SCI group.

Table 3.1 : Least squares means and standard errors (±SEM) for weights at weaning, 12 month and 18 month of calves, pre-weaning, weaning – 12 months gain and 12 months – 18 months gain, as well as hip height of the cows, for short (SCI) and long (LCI) calving interval

	SCI		LCI		Test of Significance
Trait	**Mean**	**±SEM**	**Mean**	**±SEM**	
Number of cows (n)	914		1592		
Hip height (cm)	135	2.01	141	2.0	*
Weaning weight of calves (kg)	222	39.8	239	44.38	*
Pre-weaning gain (kg/day)	1.01	0.14	1.25	0.16	*
Age at weaning (days)	221	3.1	189	4.0	*
Yearling weight of calves (kg)	348	72.38	349	77.48	n/s
Weaning – 12 months gain (kg/day)	1.15	0.12	0.92	0.14	*
18 month weight of calves (kg)	385	44.33	354	46.84	*
12-18 months gain (kg/day)	0.21	0.01	0.03	0.01	*
* $p < 0.05$					

3.5 DISCUSSION

Since the SCI cows were significantly smaller in size than the LCI group, it is likely that early and regular reproduction restrict mature size. Under extensive conditions, small size is a desirable adaptive attribute, generally associated with early and regular reproduction. This may be ascribed to high inherent fertility of the tropically adapted, synthetic Santa Gertrudis breed, which offers more flexibility under stressful conditions to increase productivity, without sacrificing expressed fertility (Swanepoel and Lubout 1992, Taylor and Swanepoel, 1999).

Seifert and Rudder (1975), Lalman *et al.* (2000) and MacNeil (2005), stated that cows with less than average live weight, tended to have lighter progeny at weaning due to reduced milk production. Reduced lactational performance may be partly responsible for the higher fertility of the smaller cows. The present study suggests that there may be a close relationship between cow fertility and progeny growth from birth to weaning age. LCI cows produced calves with the highest pre-weaning growth and the heaviest weaning weight. The least fertile cows were generally the heaviest (McMorris and Wilton 1986, Nesamvuni, 1995, Heuer *et al.,* 1999) and larger (Olson, 1994, Haile-Mariam *et al.,* 2004, Chase *et al.,* 2005), with better udders (Taylor, 1995), with which they produced more milk (Van Raden *et al.,* 2004, Windig *et al.,* 2006). They were mostly those that missed at least one calving season. Perhaps they were able to recover more rapidly from the stress of reproduction and nursing a calf and build up better body reserves for a subsequent calving.

Reduced lactational performance as such has been suggested as a contributing factor to the improved fertility in cattle (Hetzel *et al.,* 1989, Davis *et al.,* 1992, Borman *et al.,* 2004). If this is the case, it can be explained by the physiological interaction between lactation and depression of ovarian function that is related to pituitary dysfunction, which is associated with lactation (Short *et al.,* 1994, Opsomer *et al.,* 2000, Hooijer *et al.,* 2001). During intense lactation, prolactin function is maximal, limiting the secretion of FSH and LH releasing factor. The duration of anoestrus is closely related to length and intensity of lactation (Hafez, 1980, Lopez-Gatius et al., 2001). Bulls were usually put with the cows two months after calving and milk production usually peaked at this stage. An attempt could be made to substantiate this by the fact that larger cows usually produce more milk (Seifert and Rudder, 1975, Bourdon and Brinks, 1983, Doren *et al.,* 1986), therefore they calved later in the season. These results do suggest a negative endo-environmental interaction between fertility and pre-weaning growth. Other authors (McMorris and Wilton, 1986, Swanepoel *et al.*, 1992, Savagea *et al.,* 2004) agree that positive correlations between cow weight and either milk production or calf weaning weight exist. Bourdon and Brinks (1983) and Doren *et al.* (1986) reported a positive influence of weaning weight on cow fertility. Small cow frame size, reduced milk production and correspondingly lighter weaning weights are actually adaptive characteristics found in tropically adapted beef cattle (Rege, 1993, Tomo *et al.,* 2000).

Davis *et al.* (1992) found compensatory growth in both the wet and dry seasons for a SCI and LCI group, with the largest proportionate difference

between the two fertility groups being in the dry season. This suggests that there may have been a correlated improvement in efficiency when feed was limited. This possibility is supported by this study, as the main compensatory growth occurred between weaning and 12 months of age, corresponding with the dry (winter) season. Compensatory growth still continued to take place in the wet season (12 - 18 months), but the difference between the growth-rate of the progeny from the two CI groups in the wet period was not as big as between the weaning and 12 month period.

Calves from the SCI group may have been better adapted to grazing at weaning due to the likely lower milk production of the cows as indicated by the lower weaning weight of the progeny. These calves were therefore better adapted to the available grazing and could express the compensatory growth after weaning. The calves from more fertile groups may have had better developed rumens, as they were older and may have had to survive on less milk and more of the natural grazing than the progeny from the less fertile group. However, no work has been done to substantiate this and it should be investigated further.

Tomo *et al.* (1999) and Corbet *et al.* (2006) have maintained that there is no genetic antagonism between high cow fertility and post-weaning growth of their progeny, provided that strict selection is practiced for both traits. Selecting for growth rate alone may lead to reduced fertility (Olson, 1994, Archer *et al.,* 1998). Meyer *et al.* (1991) reported a favourable genetic correlation between reproduction and growth traits in cattle, and Wolfe *et al.*

(1990) also concluded that selection for weaning weight, final weight and muscling score had no detrimental effects on age at puberty in heifers. MacNeil (1988) also reported that male progeny with a relatively high growth rate were produced by cows which tended to be more fertile. This was also supported by Moyo *et al.* (1996).

Hetzel and Mackinnon (1989) concluded that high lifetime cow fertility measured in terms of the estimated breeding value for pregnancy rate, was not incompatible with the post-weaning growth rates of their progeny. Compensatory growth took place in the progeny of the high fertility group to such an extent that at 12 months of age there was no significant difference in the weights of the progeny between the high and low line fertility groups.

3.6 CONCLUSIONS

Cows of higher lifetime fertility (SCI) are smaller in size, have significantly lighter calves at weaning. Early and regular reproduction may restrict mature size. A negative endo-environmental correlation exists between fertility and pre-weaning calf growth.

Compensatory growth occurs after weaning especially in progeny from more fertile cows. The high post-weaning growth rates of the progeny of higher fertile cows therefore minimise the weight advantage of the calves from the less fertile cows even though the latter weaned calves with higher weights. The result is that at 12 months of age there is no significant difference in

weight between the two groups. Post-weaning growth rate is therefore compatible with high cow fertility.

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CHAPTER 4

EFFECT OF HEIFER FRAME SIZE ON THEIR SUBSEQUENT REPRODUCTIVE PERFORMANCE AND ON THE PRE-WEANING PERFORMANCE OF THEIR CALVES

4.1 ABSTRACT

The effects of heifer frame size (FS) on their subsequent performance and the pre-weaning growth of their calves were evaluated using records collected from 1989 to 1998 from the Waterburg Estates at Otjiwarongo, Namibia. Based on hip height at 18 months of age, heifers were assigned to three different frame size (FS) groups: small (< 124 cm), medium (125 to 135 cm), or large (>136 cm). Calving rate (CR), calving date (CD), calf survival rate (CSR), reproductive efficiency (SANDEX), weaning rate (WR), birth weight (BW), weaning weight (WWT), pre-weaning ADG (P-ADG), and kilograms of calf produced per cow bred (KCB) were collected from first (n = 830), second (n = 623) and third and greater-parity (n = 571) cows. Frame size of heifers significantly influenced ($p < 0.001$) their calving rate as second-parity cows. In spite of heavy culling of cows that had large FS as heifers, calving rates of second parity cows in this category were 41% less than that of second parity cows that had small and medium FS as heifers. In third or greater-parity cows, CR was greater ($p < 0.05$) for small FS than for medium and large FS. CSR was similar for heifers with a small, medium and large FS for the first, second and third and greater parity groups. Weaning rates of large FS (34.2 ± 11.27), second-parity cows were less ($p < 0.001$) than those of small (82.9 ± 5.58)

and medium (79.0 ± 4.67) FS animals. Among all parity groups, BW of calves born to large FS were significantly higher (p < 0.05) than those of small and medium FS cows. Calves weaned by small FS animals as first parity cows, had lower (p < 0.05) WWT than those weaned by medium and larger FS, but large FS females weaned heavier calves (p < 0.05) than small and medium FS females in the third and greater-parity group. In first parity cows, calves of large FS had greater P-ADG (p < 0.05) than those from small FS, but in second parity cows the calves from medium FS (p < 0.05) out performed those of small and large FS, while calves from third and greater parity cows of medium and larger FS had greater (p < 0.05) P-ADG than cows with a small FS. Male calves were heavier (p < 0.05) at birth, at weaning and grew faster (P-ADG) than their female counterparts. KCB was similar among small and medium FS cows, but both tended to be greater (p < 0.05) than KCB of large FS cows and as second parity cows the small and medium FS cows had an even greater (p < 0.001) advantage over the large FS animals. Small and medium FS females calved earlier, and had greater calving rates and weaning rates, as well as greater kilogram of calf produced per cow exposed than the large FS females. The performance (fertility and the growth performance of their calves to weaning) traits of the large FS were generally similar to those of smaller cows in the third and greater parity. Due to the later calving dates the reproductive efficiency (SANDEX) of large FS at first, second, third and greater parity were lower (p < 0.001) compared to the small and medium FS. Therefore, selecting cattle for the hot and dry climatic regions of Southern Africa, under extensive management conditions and with limited supplementary feeding, the recommended cow frame size should be a

medium frame. These animals have similar levels of fertility compared to small framed cows, but with similar or even better growth performances than large framed cows.

4.2 INTRODUCTION

In the late seventies and early eighties, there was a general trend in cattle farming to select large framed animals. The preference for increased frame size in cattle may have been justified, due to the favourable correlation that exists between frame size and growth rate in beef cattle (Olson 1994, Du Plessis *et al.,* 2005). Large frame sizes favour high input systems of beef cattle production. However, beef cattle production in Southern Africa is predominately practised extensively in areas with limited cropping potential. Environmental factors such as low and unpredictable rainfall, low soil fertility and high ambient temperatures not only limit crop production but also place limits on pasture production. Reduced levels of nutrient production from the natural pastures regularly limit cattle performance under extensive conditions. Furthermore, Long *et al.* (1975), Jenkins and Ferrell (2003), Llewellyn (2003) and Du Plessis *et al.,* (2005) reported that genetic differences among herds and cattle breeds for mature size affect efficiency of cattle, due to differences in nutrient requirements for growth and maintenance of heifers and of cows. The requirements for lactation and the finishing of calves also follow this principle. Although the general shape of the growth curve is not different, regardless of frame size, cattle of similar age or weight will not be at similar points on the growth curve, if they differ in frame size. Anderson (1990),

stated that independent of breed effects, increased frame size results in increased rate of growth, increased time required to reach a specific carcase grade, decreased fat thickness and marbling at equal weight, and increased weight at equal fat thickness. Since large framed cattle are actually less mature than small framed cattle at equal weight or age, their gains during the growth period are more efficient. This is because at that age the large framed cattle are gaining more muscle, which contains more water, and less fat. The latter obviously contains a great deal of energy. However, when fed to equal carcass composition, large and small framed cattle are usually similar in efficiency. The effect of cow frame size on various measures of efficiency have been experimentally evaluated by Carpenter *et al.* (1972a,b) Klosterman *et al.* (1968b), Kress *et al.* (1969), Brown *et al.* (1972a,b), Long *et al.* (1975), Morris and Wilton (1976), Morris and Wilton (1977), and Buttram and Williams (1989). These authors studied the effect of frame size in crossbred populations, which makes it difficult to determine whether the differences in performance of the cattle were attributable to differences in frame size or breed composition (Olson, 1993). Furthermore, the results presented to date are mostly generated under intensive feedlot conditions. Therefore, under extensive management conditions with limited inputs, the effect of frame size on female fertility traits and breeding efficiency may be negative. Vargus *et al.* (1999) attempted to explain the influence of frame size on production traits in Brahman cattle in the hot and humid conditions of Florida, while Du Plessis *et al.* (2005) aimed at quantifying herd efficiency between breeds based on the average mature weight of the different breeds. It was assumed that variation within breeds evaluated would be similar and were not taken into account

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fully. Information on herd efficiency within a breed, differing in frame size is limited under extensive management conditions. The aim of this research was to study the effect of frame size on the reproductive and pre-weaning growth performance of pure bred Santa Gertrudis cattle under the arid sub-tropical (hot and dry) conditions of Southern Africa.

4.3   MATERIAL AND METHODS

The data were collected from first parity (n = 830), second parity (n = 623) and third or greater parity (n = 571) Santa Gertrudis females born between 1988 and 1998 on the Waterburg Estates at Otjiwarongo, Namibia and collated with registration records maintained by the Santa Gertrudis Cattle Breeders Society in Bloemfontein, South Africa. The geographical coordinates of the Waterburg Estates are 17° east, 20.5° south and 1 500 m above sea level. The ranch comprises an area of 55 000 ha in size, of which 42 000 ha was used for commercial cattle ranching. The herd was kept on extensive natural pasture from which the heifers and calves had to acquire their nutritional needs supplemented only by a salt-phosphate lick. The natural pasture can be classified as "thorn bush savannah". The vegetation in the area includes woody species such as *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca* and grass species, *Eragrostis rigidior, Panicum maximum* and *Digitaria eriantha*. A short duration grazing (less than 3 weeks) and long rest (5 – 8 month) rotational grazing system was practiced.

Average annual rainfall for the specific area since 1872 - 1979 was 485 mm, but from 1979 - 1998 the average was only 403 mm (drought). The frequency

of rainfall is denoted by approximately 45 days of rain per annum mostly falling in summer, with a 35% average deviation from the annual rainfall average. Rainfall has a seasonal distribution with 80 - 90% of the rainfall occurring between October to March and with evaporation potential in the region of 2600 to 2800 mm per year.

Average year-round temperature is approximately 20°C, with average maximum temperatures of 32°C for the hottest months and average minimum temperatures of 3°C for the coldest months. The area experiences approximately 30% wind-free days, while the average wind speed varies between 3 to 6 meters per second. The soils are predominantly sand and loam, with scattered areas comprising acid granite.

In order to determine the effect of frame size on the reproductive and pre-weaning performance of the cattle in this herd, the heifers were assigned to small (< 124.0 cm), medium (125.0 to 135.0 cm), and large (> 136 cm) FS groups based on their 18-month hip height measurements. The mean hip height for the group of heifers selected for this trial was 128.3 cm. Similar guidelines used in studies conducted by Buttram and Willham (1989) and Vargas *et al.* (1999) were applied to allocate heifers to the various groups. According to the results presented by, Buttram and Willham (1989), Olson (1994) and Vargas *et al.* (1999) hip height of heifers taken at approximately two years of age is significantly correlated with mature size. Therefore, once allocated to a frame size group at 18 months of age (based on hip height measurements) they were not re-allocated another frame size group for later

parities. Females with physical defects (e.g. Skew mouth, over or under shot jaw, devils grip, udder, feet, and leg problems) or reproductive disorders (e.g. not pregnant) were eliminated from the study.

All sires used were purebreds obtained from other purebred herds or bred from own herds. However, own-bred bulls comprised the majority of the bulls used in the breeding program. Bulls were not selected on size or specifically allocated to a cow frame size group based on the size of a sire, but rather applied to various cow groups according to a fixed breeding strategy of the herd and to avoid inbreeding. The sires used for breeding purposes were tested for fertility and sheath washed for vibriosis *(Compylobacter foetus)* and trichomoniases *(Trichomonas foetus)* before the onset of the breeding season. Three weeks before the breeding season commenced semen were collected by means of electro-ejaculation and the breeding soundness examination endorsed by the society of animal Theriogenology (Ball *et al.,* 1983) served as the guidelines for the evaluation of spermatozoa.

A 90-day breeding season for the heifers and a 60-day breeding season for the cows were used in the study. Heifers were first bred at approximately 18 to 24 months of age. Calves were born from October to early December. Calves remained with their dams on natural pastures for the small, medium and large FS groups until weaning early in June. All calves were weaned on the same day and grouped according to sex.

Pregnancy diagnosis of the cows was done when the calves were weaned. Calving status was determined from calving records and coded as a categorical trait (1 = calved, 0 = did not calve).

Reproductive traits recorded for the dams included calving rate (CR), calving date (CD), calf survival rate (CSR), weaning rate (WR) and cow reproductive efficiency (SANDEX). The production traits measured on their calves were birth weight (BW), weaning weight (WWT), pre-weaning average daily gain (P-ADG) and production efficiency per cow (KCB). Calving rate (CR) was calculated as the number of cows that calved subsequent to the breeding season as a percentage of exposed during the breeding season. Calf survival rate (CSR) was the percentage of calves born alive and that survived to weaning (1 = survived, 0 = died before weaning). The calving date (CD) was obtained from the records supplied by the South African Santa Gertrudis Cattle Breeders Society and reported as the average days needed for a FS group to complete a calving cycle where day 0 is considered as the first day of the calving season. Weaning rate is calculated by the number of cows bred divided by the number of cows that weaned a calf (1 = weaned a calf. 0 = did not wean a calf). Production efficiency (KCB) per group was expressed in kilograms of calf weaned per FS group divided by the number of animals bred in each group, while the reproductive efficiency (SANDEX) of each FS group was calculated by means of the following formula:

$$200 - \{(X / Z) \times 100\}.$$

Where X = Age of cow at last calving in days. Z = 913 + (365 x [number of calvings] – 1).

The data on reproductive traits for heifers of different frame size and the productive traits of the claves were analysed separately for the first-parity, second parity, and third and greater-parity cows. Only cows with complete production and reproduction records were included in the analysis. Using a least squares model that included the fixed effects of year of birth, heifer frame size, and their interaction effects, resulted in no significant interactions occurring when the data for hip height of heifers at 18 months of age were analysed. These factors were subsequently deleted from the original model. The data were then re-analysed using the reduced model. Year of birth, heifer frame size were the main effects included in the final model used to evaluate the response variants associated with reproductive traits of the dams and production traits of their calves in first, second, and third and greater parity cows and further included a random error constituent in the model. Analyses for the following reproductive traits of CD, CSR and production traits of BW and WWT included the additional effect of the sex of the calf (SEX). The sex of the calf did not significantly influence CD, CSR, BW and WWT in the small, medium and large frame groups. Thus, sex of the calf was not incorporated in the final model for analysis. All possible two-factor interactions were included in the preliminary analyses. None of the two-factor interactions influenced any of the variables significantly (P>0.21), and were subsequently not incorporated in the original model. Data were analysed by least squares ANOVA using the GLM procedure of SAS (1995) and are presented as least squares means ± SEM.

4.4   RESULTS AND DISCUSSION

The effect of heifer frame size on calving rate was a highly significant ($p < 0.001$) source of variation in second parity cows and a significant ($p < 0.05$) source of variation in the third or greater parity cow groups (Table 4.1). Frame size did not affect first parity cow groups with the small, medium and large frame size having calving percentages in excess of 90%. Similar results with reference to calving rates were reported by Taylor and Swanepoel (1999) in first parity Santa Gertrudis cows. Frame size was not expected to influence CR in first parity cows because the majority of heifers were exposed to breeding at between 18 and 24 months of age, when most of these heifers should have reached puberty.   Morris (1980) and Vargas *et al.* (1999) reported similar results in first parity Brahman cattle of different frame sizes. Du Plessis *et al.* (2005) recorded higher heifer pregnancy and calving rates in small framed indigenous cattle compared to a medium sized locally developed breed and the large framed continental breed under arid sub-tropical conditions. Contrary to these results, Steenkamp and Van der Horst, (1974) noted higher reproduction rates in large and medium framed Afrikaner cows compared to small framed cows of this breed on natural pasture. Buttram and Willham (1989) suggested that the interaction between frame size and the nutritional environment indicate that if heifers are to be raised under less than optimal conditions, then smaller cattle, maturing earlier and at lighter weights, are likely to be more desirable.   Calving rate of small and medium frame size heifers surpassed ($p < 0.001$) that of the large frame second parity cows by more than 28% (Table 4.1). In a study conducted by Vargas *et al.* (1999) in Brahman cattle the lower calving rate in large frame second parity cows was

ascribed to the low calf survival rates of second parity large frame size females. Results from this study indicate that substantially more cows were eliminated due to not producing a calf in the large and medium frame sized second parity groups than that reported by Olson (1994) and Vargas *et al.* (1999) in Brahman cattle. The advantage of higher calving rates in small frame size second parity compared to the large and medium frame size was due to higher pregnancy rates in the small frame size, and not to low calf survival rates or increased incidences of dystocia. Rather, the reduced pregnancy rate observed in the large frame size is probably due to increased body maintenance requirements, although these were not measured and the stresses of lactation experienced under hot and dry extensive pasture conditions being highlighted in the second parity large frame animals. Buttram and Willham (1989) and Olson (1994) in beef cows and Hansen *et al.* (1999) in dairy cows observed that cows with a larger mature size tended to have lower conception rates while lactating with their first calves. The advantage of higher calving rates ($p < 0.05$) for small ($91.5 \pm 3.81\%$) compared to the medium ($84.5 \pm 4.00\%$) and large size ($82.2 \pm 5.30\%$) was also noticeable in the subsequent third and greater parity cow group in the present study. Calving rate improved from $45.4 \pm 6. 26\%$ to $82.2 \pm 5.30\%$ in third and greater parity for large frame size cows, resulting in an increase of 36.8% in calving rate. What should be born in mind is that more LF heifers were eliminated as cows due to not conceiving. Thus, the group eventually consisted of a select population of cows that are possibly more fertile than those that have been culled. It appears that frame size does not affect calving rate to the same extent once the cows have reached the third and greater parity group. From

the results obtained, it is evident that these cows were able to calve regularly in spite of the apparent negative association between frame size and a stressful environment once they have reached maturity. It is generally accepted that small body size is an adaptive attribute in stressful environments. Therefore, smaller framed animals have higher reproductive rates than large framed animals.

Calf survival rate was not affected by heifer frame size in first, second, third and greater parity cow groups (Table 4.1). This is in contrast with results reported by Fitzhugh *et al.* (1973), Cartwright (1974), Vargas *et al.* (1999) and Chase *et al.* (2005) who found that larger cows have lower calf survival rates than smaller framed cows.

Perhaps it was surprising to note that weaning rate was not affected by frame size in first parity cows as represented by the results in Table 4.1. The large cow frame size first parity cows had only a 4% lower weaning rate than small and medium frame size first parity cows. Vargas *et al.* (1999) reported a highly significant difference ($p < 0.001$) in WR, in first parity cows where the small and medium frame size cows out-performed the large frame size cows by 30%. Tawonezvi *et al.* (1988) and Du Plessis *et al.* (2005), noted significant differences between various breed types and frame sized cows and Chase *et al.* (2005) also found that weaning rate was considerably lower for large frame size first- and second-parity cows compared to small and medium frame cows. They attribute the difference in WR to the increased incidences of dystocia and calf mortalities experienced by the large frame cows.

Table 4.1 :   Least squares means (±SEM) for calving rate (CR), calf survival rate (CSR), weaning rate (WR) and overall productivity (Sandex) by frame size for parity groups of Santa Gretrudis cattle.

	First-parity		Second-parity		Third and greater-parity	
Frame size	n	%	n	%	n	%
CR (%)						
Small	134	94.0 ± 2.80^a	115	87.8 ± 6.04^c	105	91.5 ± 3.81^a
Medium	498	90.4 ± 4.25^a	422	84.3 ± 4.35^c	388	84.5 ± 4.00^b
Large	198	92.0 ± 3.01^a	86	45.4 ± 6.26^d	78	82.2 ± 5.30^b
CSR (%)						
Small	126	92.8 ± 6.10^a	91	93.2 ± 4.48^a	92	93.1 ± 4.56^a
Medium	456	93.6 ± 4.02^a	343	91.3 ± 5.12^a	331	91.8 ± 9.33^a
Large	166	86.2 ± 8.25^a	55	87.2 ± 9.87^a	68	93.0 ± 5.66^a
WR (%)						
Small	134	84.8 ± 4.33^a	115	82.9 ± 5.58^c	105	86.6 ± 5.42^a
Medium	498	84.0 ± 3.87^a	422	79.0 ± 4.67^c	388	89.2 ± 4.20^a
Large	198	80.6 ± 15.16^a	86	34.2 ± 11.27^d	78	80.4 ± 5.82^a
Sandex						
Small	134	94.0 ± 2.80^a	115	92.0 ± 2.33^c	105	90.8 ± 3.25^c
Medium	498	90.4 ± 4.25^a	422	90.6 ± 2.87^c	388	87.2 ± 2.82^c
Large	198	91.5 ± 3.01^a	86	78.3 ± 5.25^d	78	73.4 ± 4.52^d

[a, b]   Means with a different superscript letter within a column and trait differ ($p < 0.05$).

[c, d,]   Means with a different superscript letter within a column and trait differ ($p < 0.001$).

A possible reason for this could be that cow frame size groups were not matched to similar sized sires in this study as was the case in the study conducted by Vargas *et al.* (1999). Frame size significantly (p < 0.001) affected WR of large frame second parity cows. Small and medium frame second parity had weaning rates of 82.9 ± 5.58% and 79.0 ± 4.67% respectively compared to 34.2 ± 11.27% in the large frame size second parity cows. The advantage in WR of the small and medium frame size over the large frame cows is predominantly the result of increased conception rates of the smaller cows. Similar results were reported by Du Plessis *et al.* (2005) in various breeds differing in maturity age, and by Olson (1994) and Vargas *et al.* (1999) in Angus and Brahman large frame cows, respectively. Frame size did not affect WR in third and greater parity cows.

Bourdon and Brinks (1983) and MacGregor (1997) reported that calving date is an important reproductive trait in beef cattle. Cows that calve late in the calving season often do not return to oestrus before the end of the subsequent breeding season (Vargas *et al.,* 1999). From the results presented in Table 4.2, frame size did not affect day of calving (calving date) in first parity cows, which calved at similar dates in the calving season. A similar trend was found in the mature cows, with no significant difference in CD for the small, medium and large frame size third and greater parity groups.

Table 4.2 : Least squares means (±SEM) for calving day (CD) by frame size for parity groups of Santa Gertrudis cattle.

Frame size	First-parity		Second-parity		Third and greater-parity	
	n	days	n	Days	n	days
Small	126	28.2 ± 3.55[a]	91	38.8 ± 6.12[a]	92	41.5 ± 4.10[a]
Medium	456	27.4 ± 3.10[a]	343	44.6 ± 5.10[a]	331	44.6 ± 4.05[a]
Large	166	33.1 ± 4.86[a]	55	66.0 ± 11.25[b]	68	52.3 ± 6.71[a]

[a, b] Means with a different superscript letter within a column differ ($p < 0.05$).

On average the large frame size cows calved only 7 days later than the small and medium frame size in the third and greater parity group. Notably, a significant effect ($p < 0.05$) of frame size was evident in the second parity with large frame size cows calving on average 25 days later in the calving season than the small and medium frame size cows at the same parity. Cows that calve early in the calving season allow themselves more chances to conceive in a compact breeding season (Evans *et al.,* 2006). Similarly calving date relative to the calving season (early, middle, or late) also can influence production efficiency. For a set weaning date earlier calving cows will wean older and generally heavier calves and use feed more efficiently than later calving cows (Marshall *et al.,* 1990). This can be expected, since Williams (1990) reported that the difference in calving dates of growing young cows is expressed more prominently when animals were under lactational stress. Lactational stress is likely to suppress cyclic ovarian activity and result in a prolonged period of postpartum anoestrus. Short *et al.* (1990) and Vargas *et al.* (1999) reported that first calf heifers had longer postpartum intervals of anoestrus and lower reproductive rates than older cows.

Sex was a significant (p < 0.05) source of variation for calf weights at birth and weaning and for pre-weaning average daily gain (Table 4.3). Bull calves were 8.7% heavier than their female counterparts at birth for all parity groups. This is in agreement with results observed in studies by Plasse (1978) and Eriksson *et al.* (2002). Bull calves further outperformed heifers in terms of all traits measured pre-weaning. Similar results were obtained by Lesmeister *et al.* (1973), Rege and Moyo (1993) and MacGregor (1997) under similar environmental conditions in Southern Africa. Bull calves were 7.1% heavier than heifers at weaning and grew 0.1 kg faster to weaning. The significant effect of sex reported in this study is in agreement with reports by Reynolds *et al.* (1982), Tomo *et al.* (1999), Vargas *et al.* (1999) and Ebangi (2000) who found that bull calves are heavier than heifer calves from birth to weaning. Ebangi (2000) ascribed these differences mainly to differences in their endocrinological and physiological functions, together with increased selection pressure for growth rate on bull calves compared to heifers.

Frame size significantly (p < 0.05) affected birth weight of calves in the small, medium and large frame size in all parity groups (Table 4.3). The large frame cows consistently produced heavier calves. Calves from cows that had large frames as heifers were on average 7.1 kg heavier at birth than calves of the small frame size in all parity groups. Swali and Wathes (2006) in Holstein-Friesian heifers, Du Plessis *et al.* (2005) in various breeds and Vargas *et al.* (1999) in Brahman cattle found a similar difference with frame size across various parity groups. These results are also in agreement with those reported by Jenkins *et al.* (1991), who found a positive within-breed phenotypic correlation (r = 0.37) between BW and adult hip height of the dam. Heavier birth weights are normally associated with later calvings within the

calving season. This agrees with the findings on calving date for the different parity groups. Although Gore *et al.* (1994), failed to confirm a relationship between BW and maternal cow frame size, the larger cows tended to produce calves with greater BW than cows of smaller size.

Table 4.3 : Least squares means (±SEM) for calf birth weight (BW), weaning weight (WWT) and pre-weaning average daily gain (P-ADG) and production efficiency per cow group (KCB) and sex of calf (SEX) by frame size for parity groups of Santa Gertrudis cattle.

Frame size	First-parity cows		Second-parity cows		Third or greater-parity cows	
	n	kg	n	Kg	n	kg
BW (Kg) SEX						
Male	381	35.1 ± 0.75[a]	274	37.2 ± 0.68[a]	270	35.3 ± 0.67[a]
Female	267	32.4 ± 0.35[b]	215	33.4 ± 0.89[b]	221	32.9 ± 0.67[b]
Small	126	32.4 ± 0.68[a]	91	34.1 ± 1.05[a]	92	32.8 ± 0.66[a]
Medium	456	35.4 ± 0.61[b]	343	36.4 ± 1.25[b]	331	34.9 ± 0.91[a]
Large	166	37.6 ± 1.43[c]	55	38.6 ± 1.75[b]	68	42.6 ± 1.25[b]
WWT (Kg) SEX						
Male	386	238.4 ± 3.75[d]	326	234.8 ± 8.55[a]	228	237.2 ± 8.35[a]
Female	315	222.6 ± 4.10[e]	279	214.2 ± 9.65[b]	187	226.4 ± 7.64[a]
Small	213	210.4 ± 8.65[a]	180	218.9 ± 9.51[a]	114	224.0 ± 9.20[a]
Medium	322	231.2 ± 6.21[b]	387	228.8 ± 11.80[a]	266	229.2 ± 9.60[b]
Large	166	244.0 ± 9.90[c]	38	222.3 ± 13.80[a]	35	232.3 ± 8.10[b]
PADG(Kg) SEX						
Male	386	1.06 ± 0.13[a]	344	0.99 ± 0.12[a]	228	1.04 ± 0.16[a]
Female	315	0.910 ± 0.15[b]	279	0.89 ± 0.10[b]	187	0.98 ± 0.14[b]
Small	213	0.83 ± 0.08[a]	180	0.89 ± 0.04[a]	114	0.89 ± 0.05[a]
Medium	322	0.92 ± 0.06[b]	387	0.99 ± 0.04[b]	266	0.94 ± 0.02[b]
Large	166	0.98 ± 0.08[b]	38	0.91 ± 0.05[a]	35	0.97 ± 0.04[b]
KCB(Kg)						
Small	134	161.2 ± 13.45[a]	115	126.2± 17.90[d]	105	152.2 ± 12.26[a]
Medium	498	158.6 ± 11.31[a]	422	123.4± 18.38[d]	388	160.4 ± 14.73[a]
Large	198	136.5 ± 18.64[b]	86	63.1± 14.30[e]	78	164.8 ± 14.92[a]

[a, b, c] Means with a different superscript letter within a column and trait differ (p < 0.05).

[d, e,] Means with a different superscript letter within a column and trait differ (p < 0.001).

Frame size significantly (p < 0.05) affected calf weaning weight in all parity groups except for second parities (Table 4.3). In the second parity cow group, calf weaning weights were not affected by frame size. However, the large frame sized cows weaned lighter calves (222.3 ± 13.80 kg) than the medium (228.8 ± 11.80 kg) frame size, but still heavier than the small (218.9 ± 9.51 kg) frame size. Results obtained by Du Plessis *et al.* (2005) for various breed types of various frame sizes reported higher weaning weights in favour of the large frame breeds. In contrast, Vargas *et al.* (1999) reported no significant difference in calf weaning weights of different cow frame size groups in second parity Brahman cattle, although the large frame size cows tended to produce heavier calf weaning weights compared to small and medium frame size cows. The lighter weaning weights of the large frame dams in the second parity cow groups in this study was probably the result of later calving dates experienced by the large framed animals. Lishman *et al.* (1984) found that early calvers produced heavier calves at weaning in two different climatic regions irrespective of feed supplementation. Morris and Cullen (1988) and Garcia Paloma *et al.* (1992) support the results that heavier weaning weights are due to the age difference between cows calving early and those calving later in the season. The results from this study agree with those reported by MacGregor (1997) and Rege and Moyo (1993) under similar conditions concluded that earlier calving associated with higher fertility would have beneficial effects on growth performance of beef cattle.

Frame size significantly affected (p < 0.05) P-ADG in all parity groups (Table 4.3). The lower P-ADG in the large frame second parity group is probably the

result of later calving dates which resulted in lighter weaning weights. Except for the second parity cow group the results are consistent with other growth traits evaluated in this study. Morris and Wilton (1976) found a positive phenotypic correlation between milk production and the frame size of the cow. According to Letholu (1983), Dionisio (1989) and Bothma (1993), 50 to 70% of the variation in weaning weight and ADG can be attributed to differences in the milk production of cows. Another explanation for the increased P-ADG of calves from large cows could be the inherent growth pattern of the calves from the large frame cows (Menchaca *et al.,* 1996), and the ability of the fastest gaining calves to consume enough forage to meet their higher nutritional demand for growth (Grings *et al.,* 1996).

Frame size was a significant ($p < 0.001$) source of variation in terms of production performance in the second parity cow group (Table 4.3). Ferrel (1982) found the weight of a calf weaned per cow bred to be more important than calf weaning weight Per se, because production per cow is a function of calving rate, calf survival rate and calf weaning weight. Under the extensive conditions of this study, in the second parity the heifers classified as small (126.2 ± 17.90 kg) and medium frame (123.4 ± 18.38 kg) performed better for this index ($p < 0.001$) than large (63.1 ± 14.30 kg) frame females (Table 4.3).

The impact of cow frame size on the production performance was greater at younger ages while they were still growing than in mature cows in this study. As the large frame size Santa Gertrudis cows matured, they seemed to have overcome the negative effects imposed by size, which was observed at

younger ages. Calf survival rates were similar to those of the small frame in all parity groups, but pregnancy rates improved and were comparable to those of smaller frame size in the third and greater parity group. It appears that small framed dams were able to meet their nutrient requirements more effectively during lactation compared to the large cows, in the second parity resulting in higher pregnancy rates.

Frame size was not expected to influence reproduction efficiency of first parity Santa Gertrudis cows in this study. Reproductive efficiency of cows is measured by means of the SANDEX formula, which is a function of the age of the animal in days at calving and the number of calves produced. Heifers in this study were not mated at puberty, but at approximately 20 months of age when the majority had already reached puberty. This is evident from the results of the calving dates reported in first parity cows (Table 4.2). However, in second and third and greater parity cow groups, the small and medium frame size were 13% more efficient ($p < 0.05$) as second parity cows and 15.6% more efficient ($p < 0.05$) as third and greater parity cows, compared to the large frame cows. Carpenter *et al.* (1971) and Du Plessis *et al.* (2005) found that cows with heavier weights at maturity produced heavier calves at birth and such cows had lower reproductive performances. Such animals also tended to have longer calving intervals and produced fewer calves per breeding season.

4.5 CONCLUSION

The results from this study clearly indicate the significant effect of heifer frame size on the subsequent reproductive performance and the pre-weaning growth of the calves, under extensive conditions in the hot and dry climate of Southern Africa. Small and medium frame sized females showed similar reproductive results and significantly out performed large framed animals. Small-framed heifers were generally more fertile compared to medium and large frame heifers as cows in subsequent parities. The results from this study also show that significantly more large framed cows were eliminated from this study due to their inability to produce a calf. The lower conception rates of large frame cows were probably due to higher nutrient requirements for growth and lactation, and not an increased incidence of dystocia as reported by other authors. The reproductive results obtained in this study suggest that a reduction in frame size should be considered when selecting productive animals under extensive hot and dry climatic conditions in Southern Africa. However, it is also evident that a small number of the heifers selected as large frame were able to calve regularly and cope with the interaction between frame size and the nutritional environment a lot better once they have reached maturity.

The heifers selected as medium frame had better production results than the small framed heifers, because their calves grew faster and they weaned heavier calves.

Reproduction rate and calf survival rate are the most important factors that determine the efficiency of the herd. Therefore, management strategies should be adapted to maximize reproduction and calf survival rate, and thus the production efficiency of the herd. Large framed animals produce calves that grow faster under feedlot conditions. However, selecting cattle for the hot and dry climatic regions of Southern Africa, under extensive management conditions and with limited supplementary feeding, the recommended cow frame size should be a medium frame. These animals have similar levels of fertility compared to small framed cows, but with similar or even better growth performances than large framed cows.

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SECTION B

CHAPTER 5

TICK BURDENS OF TROPICALLY ADAPTED BEEF CATTLE AS INFLUENCED BY SELECTED PHYSICAL AND PRODUCTION TRAITS

5.1   ABSTRACT

The objective of this study was to determine the effect of traits such as age, sex, body weight, body length and height, body condition score (BCS), coat score (CS), skin thickness and average skin surface temperature on tick burdens of a tropically adapted beef breed. Bonsmara cattle (n = 143) were used to measure visible tick counts, body condition score, coat score, skin thickness, body height and length, body weight, body surface temperature, gender and inter-calving period. Measurements were taken for a period of eight months from April to December. All animals were managed extensively on natural and cultivated pastures near George in the Southern Cape. Female animals had significantly ($p < 0.05$) greater tick infestation (37.9 ± 2.7) compared to male animals (16.5 ± 1.2). Age was a significant factor ($p < 0.001$) with the younger animals below two years having (46.4 ± 5.26) more ticks than those of two years and older (20.1 ± 2.44). A significant negative correlation (r = -0.29, $p < 0.001$) was reported between the infestation of ticks on the animals and the age of the animal. Animals with an average body weight below 250 kg had 42% ($p < 0.05$) more ticks compared to animals with a body weight above 250 kg. Age of the animal and weight were highly

correlated (r = 0.70, p < 0.001), while the correlation between the number of ticks per cow and the mean weight was negatively correlated (r = -0.37, p < 0.001). Skin surface temperature significantly influenced tick infestation on the animals (p < 0.001). The degree of infestation increased as body surface temperature exceeded 30º C. Coat score, skin thickness, body condition score and inter calving period did not significantly influence tick infestation on the animals. The infestation of ticks on the animals was significantly influenced by body height (p < 0.019) and body length (p < 0.001). Animals smaller than a 130 cm in height had a significantly (p < 0.05) greater tick infestation (36.5 ± 5.0) compared to animals taller than 130 cm (21.2 ± 1.5). This trend was also observed for body length. Animals with a body length shorter than 145 cm had a greater (p < 0.05) average tick infestation of 41.3 ± 4.5 compared to 23.2 ± 1.3 for animals longer than 145 cm, indicating a 44% greater tick infestation for the shorter animals. The selection of cattle for adaptability and thus increased production under subtropical conditions, through resistance to ticks should be for animals of medium frame sizes having smoother coats that are able to dissipate heat effectively.

5.2 INTRODUCTION

Beef cattle in the tropical regions of the world are exposed to varying levels of challenge from endo- and ecto-parasites and other environmental stresses. Unless they are controlled, these parasites may cause diseases, reduced productivity and fertility and often result in mortalities of livestock (Frisch and Vercoe, 1984, 1998, Wambura *et al.,* 1998). Solomon and Kaaya (1998) and

Aerts and Nesheim (1999), reported that the effects of ticks are diverse, including reduced growth and milk production (Jonsson *et al.,* 1998), disfigured hides and the transmission of tick- borne diseases (Jutzi, 2003). The limitation of tick burdens is therefore imperative, as heavy infestations have devastating effects on productivity (Wambura *et al.*, 1998, Eisler *et al.,* 2003).

The predominant tick- control method, based on the use of *acaricides,* is becoming increasingly expensive (de Castro and Newson, 1993, Minjauw and McLeod 2003), and its effects are not always as desired. This may be due to the development of resistance in ticks and the increase in tick- infested grazing territories (Wambura *et al.*, 1998, Bianchi *et al.,* 2003, Foil *et al.,* 2004). Tick resistance to *acaricides* has proved to be a major problem in their control, mainly because most resistance arises from the *Boophilus* species as well as many multi hosts ticks, which may have five generations per year. A wide range of *acaricides* are frequently required and are currently available to control common cattle ticks. Gertenbach (2001) stated that the problem is exacerbated by the high input costs associated with the development of new *acaricides* and the small profit margins generated in beef cattle production. World economic losses from ticks are estimated at 7 billion dollars annually (Brossard, 1998). It is of great importance to use alternative tick control methods such as natural host resistance, integrated pest management (Mooring *et al.,* 1994), and *neem* seed extract (Webb and David 2001), either solely or in combination with reduced chemical application (Gertenbach, 2001). This approach would bear an immense social and economic impact on

livestock farmers in developing countries and reduce the costs incurred on *acaricides* (Wambura *et al.*, 1998). Furthermore, it is emphasized that the ability to reduce costs, increases market flexibility and meet consumer demands are all essential components of increased profitability (Frisch *et al.*, 2000).

Wambura *et al.* (1998) stated that the breed of cattle that occurs in a given environment has a major effect on the level of tick infestation. Farming with high host resistance breeds is the most important strategy for controlling ticks, but no breed is totally resistant to ticks. In most commercial beef herds, the best long-term method available for tick control, is the use of tick- resistant *Bos indicus* breeds (Frisch, 1999). Studies conducted by Utech *et al.* (1978) Utech and Wharton (1982) and Mattioli *et al.* (2000), showed that *Bos indicus* cattle are more pre-dominant in tick resistance than *Bos taurus* cattle, with very few resistant animals found in the *Bos taurus* cattle breeds. De Castro and Newson (1993) and Wikel (1996, 1999) defined host resistance to ticks as the innate ability of a host, once primed, to mount an immune response to components of the saliva of feeding ticks, thereby killing or debilitating them.

Obviously, total tick resistance should be the ultimate aim. This is technically feasible and is hopefully permanent (Frisch, 1999). In a study conducted by Scholtz *et al.* (1989), they noted that it is possible to select cattle genetically for resistance to ticks, and that breed resistance to ticks is highly heritable. Furthermore, Frisch (1999) stated that host resistance is the single most important factor affecting the economics of tick control. It is a low cost,

permanent solution requiring no extra resources and incurring no additional costs to generate a given amount of product. The situation in South Africa is quite complicated because the livestock industry is affected by two single host and five multi host tick species which are of great economic importance (Scholtz *et al.*, 1989). Therefore, the use of tick- resistant cattle breeds offers a practical and economic approach to the alleviation of the losses caused by ticks (Utech and Wharton, 1982).

Based on these facts, future alternative methods will have to be sought in order to limit costs associated with the control of tick- borne diseases and their associated production losses. A possible logical approach would be to select animals within breeds, or use breeds that are known to have traits that make them more adapted to the environmental stresses of the sub-tropical and the tropical regions. The purpose of this study was to determine the effect of certain traits on tick burdens of a tropically adapted beef breed.

5.3   MATERIALS AND METHODS

The research was conducted from autumn (April) to mid summer (December), on a beef cattle farm in the George area, Southern Cape region, South Africa (latitude 33.51° South, and a longitude of 22.31°East). Maree and Casey (1993) classified the climate in this area as temperate coastal with warm summers, cool winters and rain throughout the year. The average maximum and minimum temperatures for the George area are 19.2 and 9.4 degrees

Celsius in the winter and 23.9 and 16.1 degrees Celsius in the summer (S.A. Weather Bureau, 2000).

The average annual rainfall on the farm for the last twelve years was 912 mm, with 60% of the rainfall occurring during the summer months (September to February) and 40% during the winter months (March to August) respectively. Cattle production is based on utilizing both cultivated pastures such as perennial rye grass (*Lolium perenne*), kikuyu grass (*Pennisetum clandestinum*) and white clover while ratstail dropseed grass (*Sporobolus africanus*) and tough love grass (*Eragrostis plana*), are the natural pasture on the farm. During the year all the animals, receive an *ad lib* supply of a phosphate-salt and trace element supplement (lick) consisting of calcium, phosphorous, copper, cobalt, manganese and iodine. During winter they are also fed ammoniated hay bales as a supplement feed. Animals had free access to clean drinking water at all times during the study.

The research involved purebred Bonsmara cattle. Sixty-five mature cows ranging from one to eight calvings (3-11 years old), twenty heifers born in 1999 (2 years old), twenty heifers born in 2000 (1 year old), twenty-three young bulls born in 2000 and fifteen mature bulls born in 1998 and 1999 (2-3 years old) were utilized. The breeding season occurred from December until April. Oestrus detection methods used were visual observation of cows three times daily (early morning, mid day, late afternoon) for an hour as well as continuous oestrus detection during the day when animals were being worked with. Cows were bred by artificial insemination, a procedure that was repeated

twice more if cows did not conceive to an insemination. Heifers were bred separately from the mature cows by breeding them a month prior to the mature cow herd. To maximize the mating rate, all female animals were joined with bulls for the period May to mid June. The calving season commenced at the end of August and continued until December. Weaning of calves occurred at an average age of seven months.

Rotational grazing was practised to ensure optimum pasture management, where the basic objective was the improvement and maintenance of pasture conditions. The form of rotational grazing used was a high production grazing system where the camp is grazed by animals until all the acceptable and desirable grass species have been grazed to a stage that will ensure rapid re-growth and high production of forage. Rotational resting of pastures was practised with a withdrawal period of at least six to eight weeks depending on the condition of the pasture.

The management of the animal's health included the following: Mid to late April- vaccination against lumpy skin and three-day stiffness disease. Heifers ranging from four to eight months of age were vaccinated against brucelloses with brucella S-19. All young animals and the bulls were vaccinated against Bovine Viral Disease (BVD) in June, while cows and heifers in calf were vaccinated against BVD after calving. In September vaccination against rift valley fever and anthrax was done. No specific dosing for internal parasites or dipping for external parasites were practiced and endo- and ecto-parasite management were combined with factors such as season, vegetation, rainfall

and condition of animals. Pesticides were used only at times when severe tick infestations occurred.

Data were collected on a weekly basis, but alternated between male and female groups. Animals were restrained in a crush for data collecting purposes. Visible tick counts were done starting from the animal's head over the whole body and ending at the tail. The ticks were not removed from the animals and the different tick species were not identified. Body condition scores (BCS) of every animal were performed using a 1 to 5 scale with 1 = very thin and 5 = excessively fat (Osoro and Wright, 1992). Every animal was coat scored (CS) using a 1 to 5 scale with 1 = excessively smooth coated and 5 = excessively woolly coated, as described by Taylor *et al.* (1995). Skin thickness of every animal was measured with a calliper behind the thirteenth rib as described by Bonsma (1981), and body length and height were measured with a calibrated measuring stick. Body temperatures on the surface of animals were taken on the neck, thorax and hind quarter with a non-contact infrared thermometer (Raynger ST, Single-point laser sighting, Standard model), and the average value of the three temperatures was used. All the animals measured were then weighed with an electronic scale in order to determine possible changes in body weight. Inter calving periods (ICP) of cows were calculated based on the records of the breeder. Animals eliminated from the trial were mature bulls that were sold or animals suffering an illness or showing signs of illness (e.g. Red water, fever, poisonings).

In order to determine which x- variables (Body weight, skin surface temperature, Body condition score (BCS), coat score (CS), skin thickness, body height, body length, inter-calving period (ICP)) were related to y (number of ticks), Pearson correlation coefficients (r) were calculated as a measure of the closeness of linear relationship between two variables. Correlation coefficients between number of ticks and all the x- variables were calculated as well as between all x- variables to test for inter- correlations. A separate linear regression analysis was performed for each x- variable against tick numbers to obtain an estimate of the proportion of the variance of tick numbers that could be attributed to the linear regression on the x- variable. The R-square was calculated representing the estimated proportion of the variance of y that can be attributed to its linear regression on x. This was done with the purpose of obtaining a more detailed account of the general trends. A stepwise regression analysis was then performed in order to select a subset of those variables (x) measured that significantly contributed to the model. The x- variable for which the regression had the highest F- value and the smallest residue mean square were selected first (p = 0.05). The variables selected were: body length, body temperature, skin thickness, CS, BCS and body weight. The R- squared for this model was 0.58, (p < 0.001). Using the above model a plot of the predicted number of ticks against the observed number of ticks showed that the predicted and observed values followed the same general trend. Data were re-analysed using a PCA factor analysis including all variables and again using a discriminate analysis including all variables. However, these methods of analysis added no additional

information and were thus not included. Data were analysed using SAS V8.1 (SAS, 2000).

5.4 RESULTS AND DISCUSSION

The means for the variables measured in this study are presented in Table 5.1.

Table 5.1 : Average (±SEM) for the age, ticks counted, body weight, body surface temp (BS temp), body condition score (BCS), coat score (CS), skin thickness, body height, body length and Inter-calving period (ICP).

Traits	n	Mean	±SEM
Age (years)	145	2.8	0.21
Ticks counted (number)	145	32.0	2.15
Body weight (kg)	145	424.2	11.15
BS temp (°C)	145	30.1	0.10
BCS (1-5)	145	3.2	0.03
CS(1-5)	145	2.6	0.10
Skin thickness (cm)	145	1.5	0.02
Body height (cm)	145	123.0	0.68
Body length (cm)	145	137.1	1.17
ICP(days)	46	432.2	13.66

Table 5.2 : The effect of gender on the mean (±SEM) tick concentrations.

Gender	n	Mean number of ticks	±SEM
Female	105	37.9[a]	2.73
Male	40	16.5[b]	1.25

Means with different [a,b] superscripts differ significantly ($p<0.05$)

The mean number of ticks reported for Bonsmara cattle of 37 ± 26.7 by Corbet *et al.* (2006) for 622 animals over a 10 year period is slightly higher than the mean of 32 ± 2.15 reported in this study.

Although considerably fewer male animals than female animals (40 versus 105) were studied, the former were significantly less ($p < 0.05$) infested with ticks than female animals.

The infestation of ticks on the animals was significantly ($p < 0.001$) influenced by the age of the animals with older animals having had fewer ticks compared to the younger animals (Figure 5.1 and Table 5.3). A significant negative correlation ($r = -0.29$, $p < 0.001$) for tick concentration and age of the animals was reported for this study. This indicates that as the animals increase in age, there is a decrease in tick infestation. Doube and Wharton (1980), Rechav (1992) and Bianchi *et al.* (2003) indicated that age, nutrition, hormone levels of the host, pregnancy and lactation can also influence natural or acquired immunity to ticks. The results obtained in this study support those of Lehmann (1993) and Kleindorfer *et al.* (2006) who studied the effect of ecto-parasites on various hosts of different ages and found that young hosts are often more affected by ecto-parasites. They ascribe their results to the higher ratio of accessible surface to body volume observed in younger animals and also

possibly to their grooming behaviour and inefficient development of certain defence capabilities.

Table 5.3: Mean ticks number (±SEM) for the different age groups of cattle.

Age (years)	n	Mean number of ticks	±SEM
1	64	33.5[a]	3.05
2	53	59.2[a]	7.48
3	17	20.3[b]	3.79
4	13	17.1[b]	1.33
5	4	20.3[b]	2.88
6	6	21.2[b]	2.44
7	6	17.6[b]	1.52
8	4	19.9[b]	2.96
9	5	22.1[b]	3.08
10	3	22.5[b]	1.59

Means with different [a,b] superscripts differ significantly ($p < 0.05$)

This contention is supported by the findings of Riek (1956) and Mooring *et al.* (1994) who observed that the susceptibility or resistance of hosts to tick infestation is based on grooming behaviour, this is poorly developed in the young animal. It's possible that host resistance to ticks may increase with increased incidences of exposure to ticks. Thus, Sutherst *et al.* (1983) reported major differences in live weight and tick resistance status among steers of different ages. The older group of steers suffered less than the younger steers that lost more weight due to tick infestation. Literature pertaining to the effect of age on tick burden in cattle is generally scarce, but a

study conducted by Brown (1984) on guinea pigs showed that age was a significant factor contributing to tick resistance. Although the animals in his study expressed significant resistance to ticks overall, it was the younger animals that were significantly more resistant than the older animals. Intermediate aged animals expressed a level of immunity that was qualitatively different from only the youngest and oldest animals. This finding suggests an age dependent, quantitative gradation in immune responsiveness. However, when the engorgement weights of ticks from each group were recorded they tended to be lighter in the older animals. These results suggest that an immune process that is age dependent mediates the mechanism of acquired resistance to ticks, which could also be similar in cattle. Wikel (1996) reviewed the role of host immunity to ticks. He deduced that tick feeding induces antibodies that vary in specificity. Furthermore, repeated or continuous exposure brings feeding ticks into contact with the immune effecter elements induced by primary infection. Primary introduction to saliva stimulates generation of memory T and B lymphocytes, which assure more vigorous immune response upon re-infestation. George *et al.* (1985) observed that in pure- bred and cross- bred *Bos indicus* cattle, resistance to ticks was acquired during an initial infestation and was expressed during the second exposure, to attain a high level by the third infestation. This may explain the reduction in tick counts with age, observed in this trial. The results presented in Figure 5.1 and Table 5.3 therefore, appear to agree with the findings presented by Sutherst *et al.* (1983) and George *et al.* (1985). Animals in this herd possibly developed adequate resistance to ticks over a number of years due to repeated exposure. These results are in contradiction with those

reported by Francis and Little (1964), Sutherst *et al.* (1979) and Lima *et al.* (2000) who observed that adult cattle presented higher burdens of *Boophilus microplus* than did calves. However, in the study by Lima *et al.* (2000) both the climatic differences between the two years of the trial, and the cattle-raising techniques adopted on the ranch in their study could have contributed to the lower infestations seen on the young animals. The calves were maintained apart from adult animals at low population densities and were thus possibly exposed to lower parasite burdens on the pasture.

Tick counts

```
150 ^
    |
    |
    |                              R² = 0.08
    |
    |        D
100 ^        B
    |B       A
    |B       B
    |B       A
    |C       A
    |E       B
 50 ^F       A
    |*       A                                        A
    |B       *       *       *       A                         A
    |A       F       E       E       *       *       *    B    A       B
    |N       C       I       H       B       E       *    *    *       A
    |K       B       C       B       A       A       A                 *
    _____
     1       2       3       4       5       6       7    8    9   10  11
```

Mean age (Years)
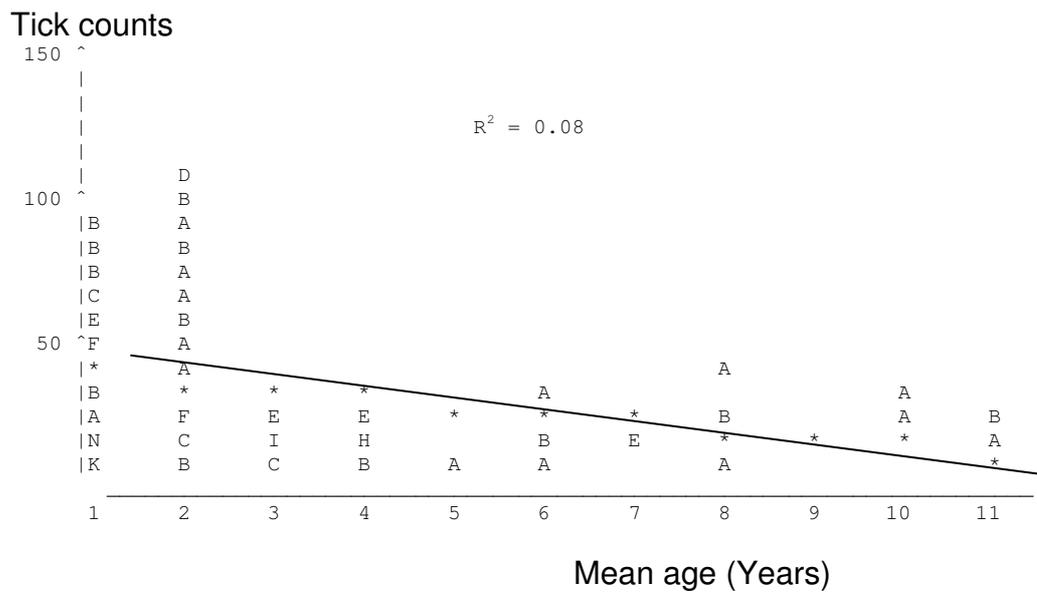
Figure 5.1 : The influence of age on the tick burdens observed in beef cattle.

Table 5.4 : Mean tick numbers (±SEM) for the different body weight groups of cattle.

Body weight (kg)	n	Mean number of ticks	±SEM
100-200	3	38.5[a]	2.06
200-300	35	38.3[a]	4.20
300-400	22	55.6[b]	8.37
400-500	30	28.2[c]	4.59
500-600	44	19.9[c]	1.20
600-700	11	21.7[c]	2.36

Means with different [a,b,c] superscripts differ significantly ($p < 0.05$)

The tick counts observed on the cattle were significantly influenced ($p < 0.001$) by the weight of the animal (Table 5.4). The trend observed in this study was for animals below an average of 250 kg to have 42% more ticks attached than animals with a body weight 400 kg and above. Animals in the 400 kg and below weight groups were also the younger animals (Figure 5.2). Furthermore, age of the animals and weight were highly correlated ($r = 0.70$, $p < 0.001$), while the correlation between the number of ticks per cow and the mean weight was negative ($r = -0.37$, $p < 0.001$). O' Rouke (1982) reported no significant increase in weight loss in un-dipped z*ebu* cross bred cattle due to increased tick infestation. Similarly Pegram *et al.* (1989) and Prayaga (2003) reported a negative correlation between the number of ticks and live weight gain in native African cattle older than one year of age. However, several authors have reported weight loss in cattle due to increased tick infestation (Sutherst *et al.,* 1983, Ervin *et al.,* 1987, Lehmann, 1993). The results presented by Norval *et al.* (1988) demonstrate that larvae and nymphs of *R.*

appendiculatus cause negligible loss in live weight of either indigenous Nkoni or exotic *Bos taurus* breeds of cattle, even at the high densities, but adults ticks did severely effect the *Bos taurus* cattle.

Tick counts
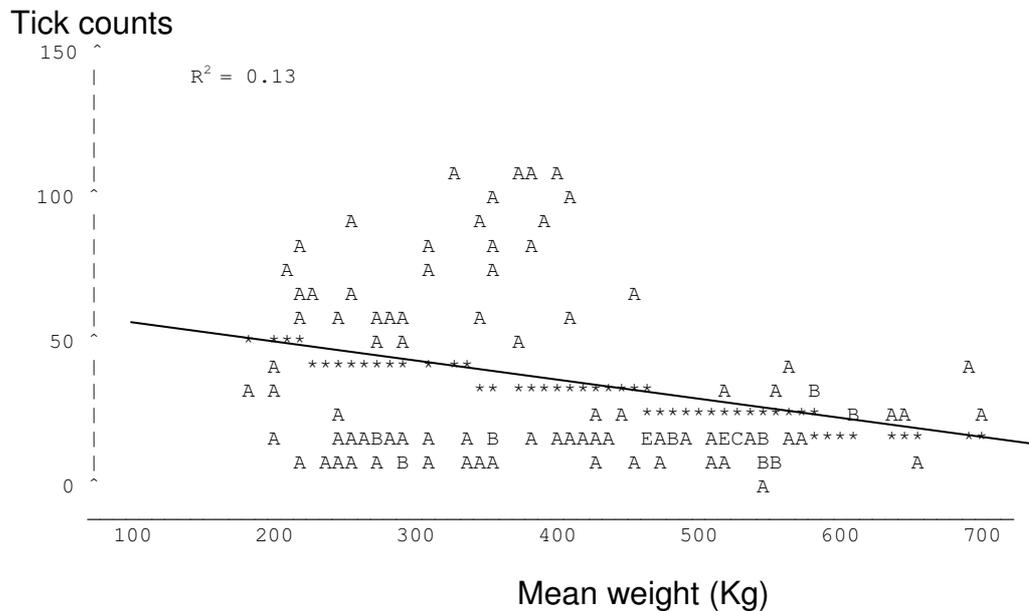
Figure 5.2 : The effect of weight on tick burdens observed on beef cattle.

In a study conducted by Ervin *et al.* (1987) with pure bred *Bos taurus* and cross bred *Bos indicus* cattle, they reported a significant negative effect on weight gain in the *Bos taurus* animals, but not on weight gain for the *Bos indicus* cross bred cattle. Similarly, Sutherst *et al.* (1983) observed that steers on the same pasture suffered a much greater loss in live weight in spring compared with summer and autumn to winter, over a two year period. The major differences between the two years were in the age, weight and tick resistance of the steers. Norval *et al.* (1989) did observe a weight loss in cattle subjected to three different levels of tick infestation. The difference in the results obtained in the study by Norval *et al.* (1989) and those presented in this study possibly can be ascribed to the difference between studies in tick

concentrations. Tick concentrations were artificially manipulated to higher levels than would possibly be expected under natural conditions in the study by Norval *et al.* (1989). Even the group exposed to the lowest level of infestation in the study by Norval *et al.* (1989) was substantially more infested than those presented in this study. This is supported by the observation that cattle in his study exhibited disturbing behavioural patterns due to the high level of infestation. Seebeck *et al.* (1971) reported that the greatest effect ticks have on British breeds of cattle is associated with a depression in appetite. These findings were supported by O' Kelly and Kennedy (1981) who found that tick infestation in cattle caused reduced appetite and disordered metabolism including nitrogen and dry matter digestibility. It would therefore seem that weight loss in cattle as a result of high tick infestation is predominantly due to a reduced feed intake affected by behavioural disturbances such as constantly rubbing, scratching, kicking and biting at ecto-parasites and not the result of nutrients losses due to feeding ticks.

Table 5.5 : Mean tick numbers (±SEM) for the different BCS of cattle.

BCS (1-5)	n	Mean number of ticks	±SEM
2.0-2.5	7	43.3[a]	7.47
2.5-3.0	43	31.9[b]	3.68
3.0-3.5	64	31.8[b]	3.72
3.5-4.0	27	31.1[b]	4.22
4.0-4.5	4	24.0[c]	6.40

Means with different [a,b,c] superscripts differ significantly ($p<0.05$)

A trend indicating that the number of ticks present on the cattle tended to decrease as body condition score improved is evident by the results presented in Table 5.5. The results of this study, although not as clearly

defined, support the findings of O'Kelly and Seifert, (1969) and Gladney *et al.* (1973), who reported that the British cattle breeds having the lowest body condition score under tropical conditions had the highest infestation of ticks. They ascribe their findings to a dietary deficiency that influences the break down of tick resistance. Furthermore, Springell (1974) and Bianchi *et al.* (2003) established that tick load on an animal is affected by breed, sex and lactation stage of the cow as well as by nutritional stress. Ultimately, these factors affect general body condition, which in turn affects blood composition, respiratory rate, appetite and eventually leads to poorer body condition scores. This is not in agreement with the results reported by Garcia *et al.* (1989) for *Bos indicus* cattle, who found no difference in tick concentrations for different body condition scores under conditions similar to the study reported here.

Table 5.6 : Mean tick numbers (±SEM) as affected by surface body temperature.

Body Surface temperature (℃)	n	Mean number of ticks	±SEM
26-27	3	12.5[a]	1.26
27-28	14	13.1[a]	0.98
28-29	8	13.9[a]	2.48
29-30	22	22.8[b]	2.41
30-31	60	33.1[c]	2.81
31>	38	48.7[d]	5.79

Means with different [a,b,c,d] superscripts differ significantly ($p<0.05$)

Except for a study conducted by O'Kelly and Spiers (1983) who reported results on body surface temperature and resistance to the tick *Boophilus microplus* in different breeds of cattle, the influence of body surface temperature on the cattle's natural resistance and susceptibility to tick

infestation appears to be limited. The results of the influence of average skin surface temperature on tick infestation in cattle are presented in Figure 5.3 and Table 5.6. The results indicate that the degree of tick infestation on cattle increases markedly as the body surface temperature starts to exceed a threshold value of 30°C. This is further supported by the highly significant (r = 0.40, p<0.001) correlation between the number of ticks and body surface temperature, indicating that as surface temperature of the animal increases, so tick infestation rates also increase. The differential responses of *Bos indicus* and *Bos taurus* cattle to heat stress have been documented (Bonsma, 1981). *Bos indicus* breeds tend to have lower rectal temperatures than *Bos taurus* breeds under heat stress conditions (O'Kelly and Spiers, 1983, Gaughan *et al.,* 1999). The results obtained in the study by O'Kelly and Spiers (1983) between different breeds of cattle demonstrated clearly that there was a positive correlation with the number of ticks carried by the animal and its rectal temperature. The results from this study support those obtained by O'Kelly and Spiers (1983). These findings are contrary to what might have been expected since it is thought that a negative correlation between tick infestation and body surface temperature would exist. Since it is assumed that increased body temperature is a defensive mechanism against parasites. Observations made in this study were that the younger animals (below one year of age) tended to have higher tick infestation and average skin surface temperatures than older animals. O'Kelly and Spiers (1983) also hypothesized that the magnitude of tick infestation and tick resistance may be influenced by the physiological status of the animal. This could explain the increased tick infestation observed in the younger animals, which tended to have higher

surface temperatures and more woolly coats than the older animals in this study. Bonsma (1981) and Taylor *et al.* (1995) ascribed the difference in body temperature and coat score in younger animals that have not reached puberty to the probability that the endocrinological functions that control thermoregulation are not fully manifested compared to older animals. O'Kelly and Spiers (1983) also noted that cattle unable to regulate body temperatures in times of heat stress tended to spend more time laying down in the shade, than animals that were more adapted. Similarly, Bonsma (1981) and Olson *et al.* (2003) noted that woolly coated animals readily become hyperthermic on hot days and as a result of heat stress stood or lay in the shade more often, where the incidence of ticks is higher than in the open or direct sun light. This behaviour could ultimately also result in reduced feed intake and subsequent weight loss in cattle.

```
Tick counts
   150 ^
       |
       |        R² = 0.16
       |
       |
       |                                              AB   A
   100 ^                                      A        A
       |                                         AA  A
       |                                          AAA    A
       |                                 A        A   A
       |                              A        BA
       |                           A   A    A  AA  B
    50 ^                           ABA      AA   A       *
       |                              A AA *********
       |                     A   A ***********A
       |         A          B *****  ***CAA A  BAE  AAAB     A
       |    AAA  AAA       *  *  *** B AA    BA ABCA BDBFCA DB   B
       |    *** ****      B A  B      A  AA  A AA      BAA
     0 ^        *                  A
         ┼──────┼──────┼──────┼──────┼──────┼──────┼──────
         26     27     28     29     30     31     32     33
```

Mean surface body temperature (^{0}C)
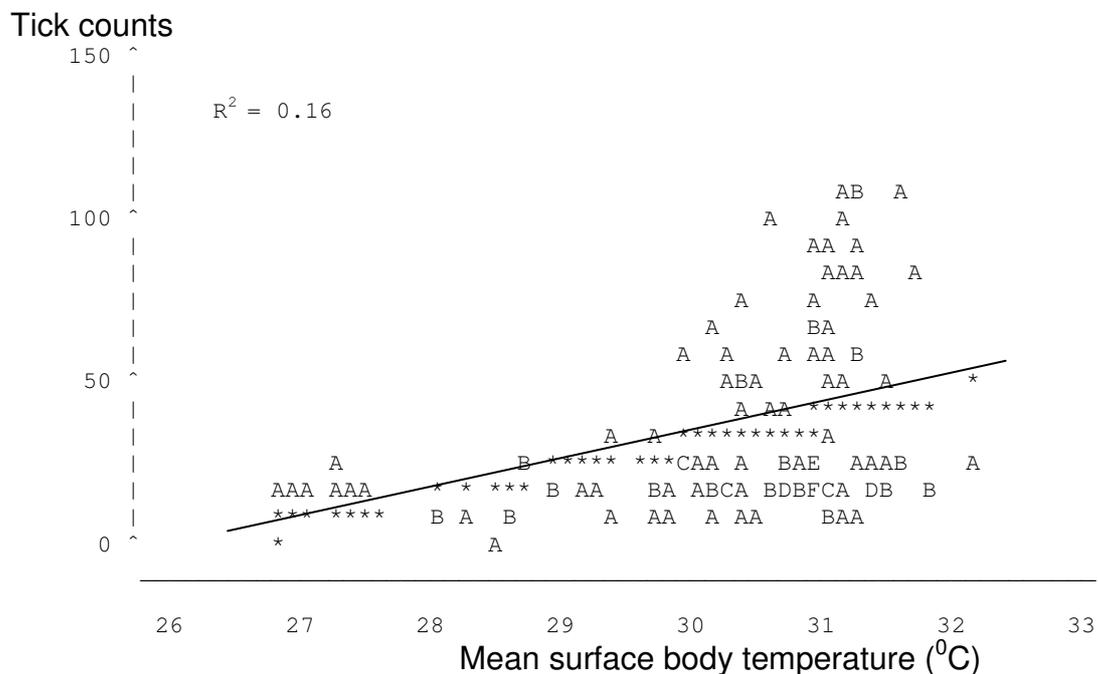
Figure 5.3 : The effect of body surface temperature on tick burdens observed on beef cattle.

Coat score did not significantly affect ($p>0.1863$) the tick counts observed in this study (Table 5.7). The results presented do however, demonstrate that younger animals had lower CS (woollier coats) compared to those animals of two years and older (shorter and hairy coats).

Table 5.7 : Mean coat score (±SEM) for cattle at different ages.

Age(years)	n	Mean Coat score (1-5)	±SEM
1	64	3.1[a]	0.15
2	23	1.8[b]	0.14
3	17	2.7[b]	0.30
4	13	2.7[b]	0.28
5	4	2.0[b]	0.17
6	6	1.7[b]	0.48
7	6	2.2[b]	0.61
8	4	2.3[b]	0.56
9	5	1.8[b]	0.31
10	3	2.0[b]	0.38

Means with different [a,b] superscripts differ significantly ($p<0.05$)

This is further supported by the significant negative correlation ($r = -0.34$, $p < 0.001$) between age and CS, indicating that as the animals reach maturity the CS decreases (coats become smoother). Furthermore, the animals with smoother coats had less ticks and as the coats became woollier the number of ticks appeared to increase (Figure 5.4). Coat type is an important aspect of heat tolerance in cattle (Turner and Schleger, 1960, Prayaga 2003) since it influences heat loss from the skin. Generally, the woolly coats of un-adapted animals are disadvantageous in tropical environments (Turner, 1962). Similarly O'Kelly and Spiers (1983) suspect increased humidity and more

equable temperatures on the skin of woolly coated animals, combined with variable diurnal environmental temperatures and solar radiation might provide a more favourable micro environment for the survival of ecto-parasites. Finch *et al.* (1984) reported significant differences in production potential in favour of animals with smooth coats compared to those with woolly coats under tropical conditions. Animals with smooth coats tend to expose ticks to the harmful effects of solar radiation from the sun more than those ticks found on woolly coated animals. Results presented by O'Kelly and Spiers (1983) demonstrate that there is an environmental component to the resistance of ticks by the host, since animals maintained in the sun carried considerably fewer ticks than animals allowed access to shade. This is further emphasized by Doube and Wharton (1980) who reported that irrespective of the breed or nutritional state of the cattle, tick infestation was higher in summer than in winter. Bonsma (1981) also noted that during summer the coat of Afrikaner cattle is smoother and they have fewer ticks than in the winter months. He ascribes this phenomenon to the smooth coat probably producing more sebum which possibly makes it more difficult for ticks to attach. The lack of significance of CS on tick counts obtained in this study could mean that the herd has been selected for production traits such as growth and high reproduction rates over a number of years therefore, it is unlikely that a large variation in coat score could be expected. Furthermore, animals with woolly coats have reduced feed intakes and reproductive rates that eliminated them from the herd.

Tick counts

```
 150 ^
     |        R² = 0.01
     |
     |
     |
     | A              B              A
 100 ^                A              A
     |                A              A                              A
     |                B              A              A
     |                B                                            A
     |                B                                            B
     |                               A              C              C
  50 ^                B                             A              D
     | B                             A              A              A
     | C              *              *              *              *
     | *              G              C              B              B
     | P              L              E              L              C
     | A              F              B              G              D
   0 ^_____
            1              2              3              4              5
```

Mean coat score (1-5)
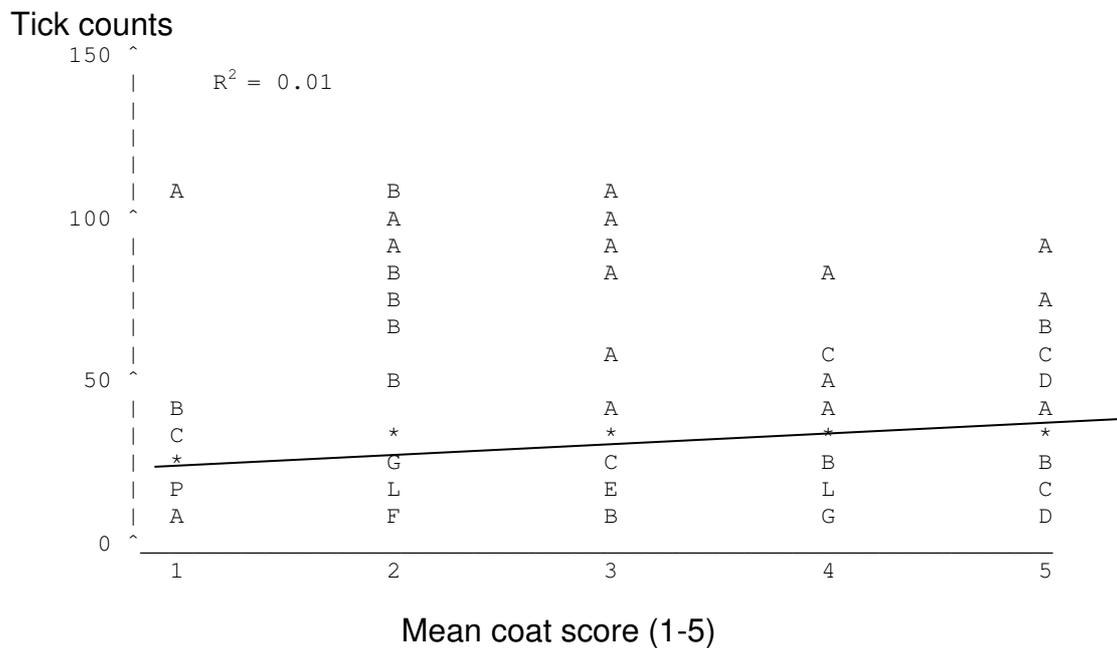
Figure 5.4 : The effect of CS on tick burdens observed on beef cattle.

Age did not significantly influence skin thickness (Table 5.8) and skin thickness also did not significantly (p = 0.2014) affect the tick numbers observed on the cattle (Figure 5.5). These observations are contrary to what would be expected since penetration by ticks through the skin should be more difficult as skin thickness increases. Furthermore the results in this study tend to be slightly contradictory, because animals with the highest BCS had the least infestation of ticks, which is further supported by the highly significant correlation (r = 0.47, p < 0.001) reported between skin thickness and body weight and between body weight and BCS (r = 0.48, p < 0.001) respectively. This indicates that body weight and BCS influence hide thickness. A possible explanation for this inconsistency could be the method used to evaluate skin

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thickness. The method used in this study was a double skin measurement using a spring calliper, which would certainly be influenced by BCS.

Table 5.8 : Mean skin thickness (±SEM) for cattle at different ages.

Age(years)	n	Mean skin thickness (cm)	±SEM
1	64	1.4[a]	0.03
2	23	1.7[a]	0.04
3	17	1.6[a]	0.06
4	13	1.6[a]	0.05
5	4	1.4[a]	0.10
6	6	1.7[a]	0.10
7	6	1.5[a]	0.07
8	4	1.6[a]	0.07
9	5	1.5[a]	0.06
10	3	1.4[a]	0.09

Means with different [a] superscripts differ significantly (p<0.05)

Tick counts

```
150 ^
    |
    |       R² = 0.01
    |
    |
    |                                      A   A    AA
100 ^                                        A   A
    |                                A   A   A
    |               A          A        A          A
    |                          A     A      A
    |            A      A         A       A
    |            A    AAA    A     A                  A
 50 ^     A    A    A    A    A         A A
    |        A        A   A   A
    |        A  A    ********************************** **
    |   *  *  ***   **  *  ****   A AABB AAAD CB  AA  AA   A         A
    |         A    AA   A  BA   ABBEB CDGAB CB   C   AA B
    |         A    A      AB AAAAA  C A  A A A     A A   A     A
  0 ^                              A
    |_____
       0.75    1.00    1.25    1.50    1.75    2.00    2.25
```

Mean skin thickness (cm)
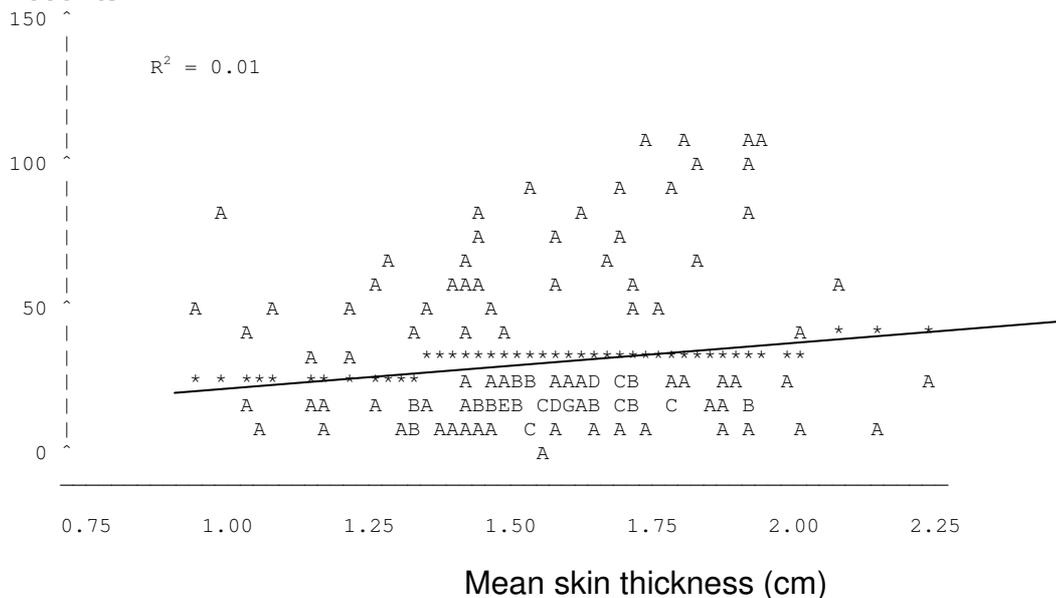
Figure 5.5 : The effect of skin thickness on tick burdens observed on beef cattle.

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The hide was measured at the thirteenth rib, while most of the ticks observed on the animals were found around the thinner skin surface areas of the ears, neck, tail setting (rectum), and udder and between the legs. Nay and Hayman (1963) and Hayman *et al.* (1966) reported variation in skin thickness associated with changes in season. They ascribe these changes in skin thickness to the differences in nutritional level between the rainy season when forage is abundant and of high quality, compared to thinner skins in the dry season when forage is scarce and of low quality. Clearly, skin thickness is influenced substantially by the way it is measured and the level of subcutaneous fat associated with increased or decreased BCS. This observation tends to support the results obtained by Amakiri (1974), who found a significant variation in hide thickness in various regions of the body, with the thinnest regions being those observed with the highest tick counts in this study. However, Bonsma (1981) stated that cattle with thicker skins were influenced least by tick concentrations, a trait which he observed more in *Bos indicus* x *Bos taurus* cross bred cattle.

Table 5.9 : Mean number of ticks (±SEM) for the different body heights of cattle.

Height (cm)	n	Mean number of ticks	±SEM
90-100	1	36.7[a]	
100-110	13	39.1[a]	6.79
110-120	36	37.7[a]	4.75
120-130	64	32.6[a]	3.65
130-140	31	21.2[b]	1.51

Means with different [a,b] superscripts differ significantly ($p<0.05$)

```
Tick counts
   150 ^
       |
       |     R² = 0.07
       |
       |
       |                               A      AA A
   100 ^                                 AA
       |                            A       B
       |             A                 A   AA
       |                      A    A  A
       |             AA  A             A
       |             A    A    B A  A      A
    50 ^     *        *** AB     A    A    A    A
       |                      ************  A              A           A
       |     A        A            ***********  A A A      A
       |                      A            ABBA ********* ****
       |             A      A A A CCAA AA  A  FCBDDADABAB AAA      *
       |             A      A  A  AA ABB    A  CAAAA A   A    A
     0 ^                                       A
       _____
         100       110       120       130       140       150
```
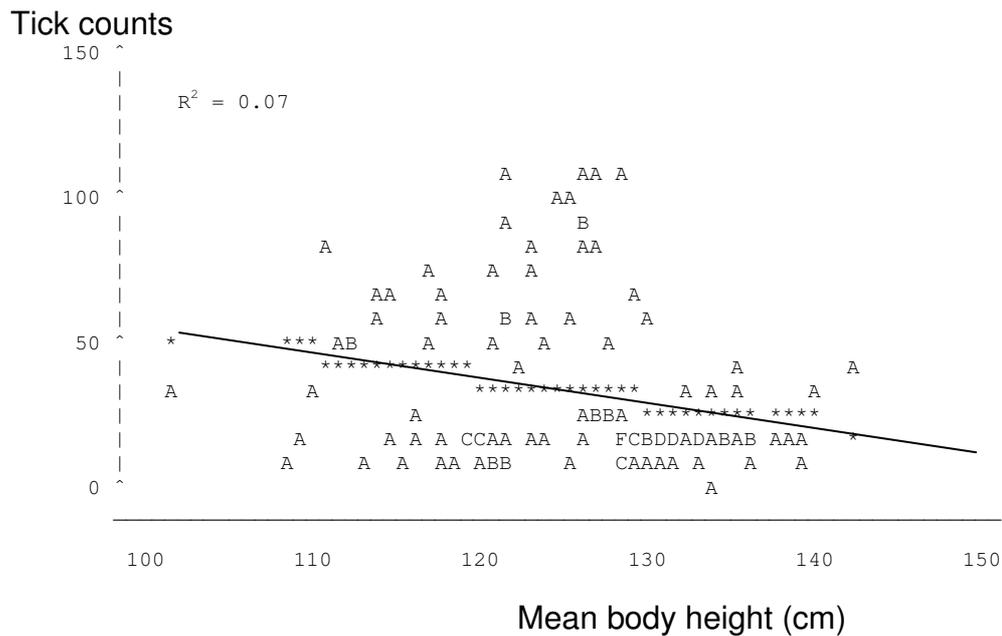
Mean body height (cm)

Figure 5.6 : The effect of body height on tick burdens observed on beef cattle.

Animals smaller than a 130 cm had significantly ($p < 0.05$) more tick counts compared to animals taller than 130 cm (Table 5.9, and Figure 5.6). The correlation between body height, and body length in this study were significant ($r = 0.87$, $p < 0.001$), supporting similar results reported by Maiwashe *et al.* (2002). The infestation of ticks on the animals were also significantly ($p < 0.001$) influenced by body length (Table 5.10 and Figure 5.7). Animals with a body length shorter than 145 cm had an average tick infestation of 41.3 ± 4.5 compared to 23.2 ± 1.3 for animals longer than 145 cm, indicating a 50% greater tick infestation on the shorter animals. These results are contrary to what would be expected because it could be argued that animals with larger surface areas would possibly allow more contact opportunities for the ticks to attach themselves. A possible explanation for these results could further support the argument that the younger animals which had smaller body measurements tended to have higher body temperatures and lighter body

weights which have shown to significantly influence ($p < 0.001$) tick burdens in this study. Lehmann (1993) also found that younger animals have a higher ratio of accessible surface to body volume than older animals, increasing tick attachment frequency per unit area.

Table 5.10 : Mean number of ticks (±SEM) for the different body lengths of cattle.

Body length (cm)	n	Mean number of ticks	±SEM
100-115	17	54.3[a]	3.27
115-130	26	35.7[a]	5.90
130-145	49	33.9[a]	4.67
45-160	52	21.3[b]	1.40
160-175	1	25.1[b]	-

Means with different superscripts [a,b] differ significantly ($p<0.05$)

Tick counts
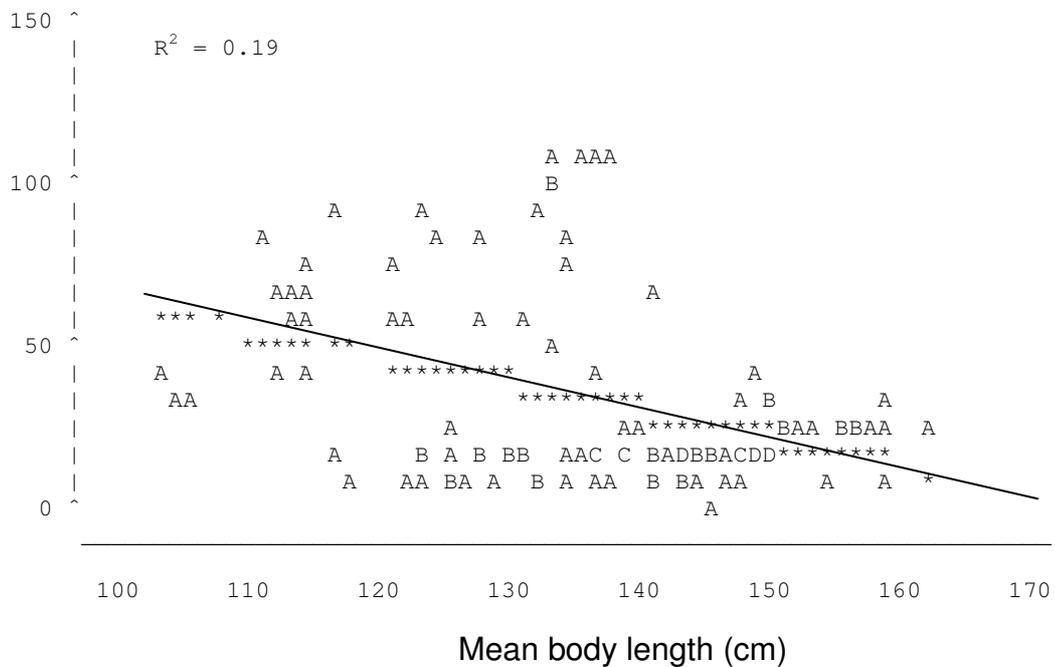
Figure 5.7 : The influence of body length on tick burdens observed on beef Cattle.

It is generally excepted that the average inter calving period is an adequate reflection of the fertility level of the herd, hence ICP can also be considered a measure of adaptability, because animals that are not adapted to a specific environment tend not to reproduce or have a low phenotypic expressed fertility. Results representing ICP (Table 5.11), clearly indicates that there was no significant trend for increased infestation to extend the average ICP of the animals (Table 5.11). The effect of tick infestation on post partum reproductive performance of cattle is not well documented. The results obtained in this study support those of Garcia *et al.* (1989) who found that the degree of tick infestation did not markedly affect the length of the intervals from parturition to first ovulation and to conception in F1 Brown Swiss x Nelore cross bred cows under tropical climatic conditions.

Table 5.11 : Average tick numbers (±SEM) for the different inter-calving period (ICP) of cattle.

ICP(days)	n	Mean number of ticks	±SEM
300-400	25	20.4[a]	1.31
400-500	15	18.7[b]	1.10
500-600	3	21.1[c]	4.74
600-700	1	21.1[c]	___
700-800	2	21.0[c]	4.38

Means of different [a,b,c] superscripts differ significantly ($p < 0.05$)

Although the direct relationship between tick burden and reproductive efficiency could not be established, there was a trend for the time from parturition to first ovulation and to conception to increase with increasing tick

load in their study. Results presented by Scholtz *et al.* (1991) indicate that the sub- fertile heifers had higher tick burdens than lactating cows or bulls. This further suggested that these heifers were either highly susceptible to tick infestation because of their physiological status, or that they did not conceive because of high tick burdens. Contrary to the former findings Teel *et al.* (1990) stated that the lower conception rates observed in cattle under tropical conditions is more a function of weight loss than the direct effects caused by tick burdens on cattle. However, reductions in external parasites with *acaricides* have been shown to improve weight responses in calves and cows as well as conception rates (Guerrero, 1987) in cows. Similar results were presented by Teel *et al.* (1990) where Angus cows with tick numbers reduced by *acaricide* treatment, lost less weight and were able to enter the new breeding season with heavier body weights than untreated cows. Although no significant effect of tick burden on ICP was observed in this study it is not unlikely that excessively high tick burdens for prolonged periods of time could adversely affect fertility in cattle.

5.5 CONCLUSION

Cattle production in South Africa is exposed to varying levels of challenge from endo- and ecto-parasites, as modified by season, geographic location and other environmental stresses. Ticks cause substantial losses in animal production by reducing growth rate, milk production, disfigured hides and the transmission of tick- borne diseases often resulting in death. Control of such parasites is vital but the use of *acaricides* is becoming increasingly expensive,

their effects are not always absolute due to the development of resistance in ticks and there is a greater awareness of health issues by consumers. Consequently, it is of great importance that alternative tick control methods either solely or in combination with reduced chemical applications will form the new strategy for controlling ticks in the future. Therefore, it is possible that 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. Applying this strategy should consider the identification of traits that could limit the concentration of ticks on beef cattle, under natural grazing conditions. The present study followed this approach and identified traits reflecting maturity and variations in age of the animal, body weight, skin surface temperature, the interactions between indicators of maturity as significant sources of variation for tick concentrations on cattle.

The results also indicated that calves younger than one year of age had 8% more ticks compared to mature animals. The possible implication for this is that mature animals should graze camps that are well rested and which offer more protection for ecto-parasites before younger animals are allowed to graze in these camps. Alternatively, camps that have a known degree of low tick infestation should be reserved for the younger animals.

The characteristics employed to denote maturity viz. weight, body height and body length confirmed this trend. Animals below 250kg had a 42% higher tick

concentration compared to animals above 400kg. Younger animals have a higher ratio of accessible surface to body volume coupled with an inadequate grooming behaviour and an immune system which is not fully developed. It seems logical that the same recommendations should be adhered to as that proposed for age, since weight, body height, body length are functions of age. These results suggest that strategic dipping programs 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.

The influence of skin surface temperature on tick concentrations on cattle in the literature is scarce. The results reported so far indicate that animals with an above average skin surface temperature tend to have higher tick burdens. This trend was observed in this study where cattle with average temperatures above 30 degrees Celsius and greater had 43% more ticks compared to animals with an average surface temperature below 30 degrees Celsius. Consequently selection for tick resistant animals could make use of these findings. Animals with a lower surface temperature could be selected as an indication of tick resistance.

Traits not significantly affecting tick concentrations on the animals were BCS, CS and hide thickness. Although not significant there was a trend for animals with a higher BCS to have fewer ticks while those with higher CS and thicker hides carried more ticks. ICP was not affected by tick concentrations. Future studies should look into the effect of skin thickness on tick burdens respectively, as the coat may have been a confounding factor. A significant

correlation between body height, body length and the tick burden an animal caries was reported in this study but may simply be a reflection of maturity status.

The selection of cattle for adaptability and thus increased production under subtropical conditions, through resistance to ticks should be for animals of medium frame sizes having smoother coats that are able to dissipate heat effectively.

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SECTION C

CHAPTER 6

6.1 INTRODUCTION

Pregnancy of the female in cow-calf operations results only following successful mating, either by natural service or A.I. Thus, the reproductive capabilities of bulls are of paramount importance because the calf sold as a weaner is the primary and largest source of income derived from a cow-calf operation. Many cattle breeders and performance testing schemes tend to conclude that factors affecting reproductive capacity in the bull can be given lower priority than production traits such as growth (Bellows and Staigmiller, 1994, Weigel 2006). Therefore, emphasis on maximum selection for production traits has tended to minimize attention given to the reproductive performance of bulls. For this reason, beef bulls have been subjected to a low selection pressure for reproductive capacity, particularly seminal quality. Coulter (1994) speculated that many cattlemen, whether conducting pure breeding or operating a commercial herd, have little or no information on the reproductive status of their bulls, particularly their yearlings. This is so, despite Trenkle and Wilham (1977) establishing that reproductive performance of both bulls and cows (du Plessis *et al.,* 2005) having a greater impact on beef economic returns than does either growth rate or product quality in a cow-calf operation. In many cases, bulls receive no form of assessment prior to sale or use (Godfrey and Lunstra, 1989). As reproductive potential in beef bulls is vast because a bull is likely to produce many offspring, the impact in a herd could be large. Palasz *et al.* (1994), Chenoweth (1981), Kennedy *et al.* (2002)

and Holroyd *et al.* (2004) estimated that approximately 30% to 40% of the bulls used for breeding are reproductively deficient. Low levels of bull fertility may contribute significantly to the low national calving average of the South African cow herd. Poor reproductive performance is the major reason cows are removed from the herd (Greer *et al.,* 1980, Freeden *et al.,* 1987, Bellows and Staigmiller, 1994), while Bellows and Short (1994) clearly show that the greatest production loss results from cows not being pregnant at the end of the breeding season. The reproductive efficiency of bulls and females both contribute to express reproductive performance of the cowherd. Brinks (1994) states that it is 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 based on low reproductive performance. He states further that as long as sires with average reproductive potential are used culling of sub-fertile cows, even when repeated every generation, would improve reproductive potential of the herd very little. This statement is supported by the results presented in the studies by Fitzpatrick *et al.* (2002) and De Jarnette *et al.* (2004).

Testicular traits such as scrotal circumference (SC) are widely used and accepted as an indication of bull fertility (Cook *et al.,* 1994, Chacon et al., 1999, Brito *et al.,* 2004, Parkinson 2004, Torres-Junior and Henry 2005). Thus, it is likely that SC is the best indicator of inherent fertility presently available. Reviews conducted by Coulter and Foote (1979) and Parkinson (2004) and studies by Brinks (1989) and Kastelic *et al.* (2001) lead to the conclusion that scrotal circumference measurements in bulls are of value for

prediction of potential sperm production and breeding soundness. However, there are a number of reports that question the relationship between SC and semen quality (Makarechian *et al.*, 1983, Williams, 1988, McGowan *et al.*, 2002). Testicular size is controlled to a large extent by genetics as numerous studies have shown that testicular size in yearling beef bulls is moderately to highly heritable (Bourdon and Brinks, 1986, Coulter *et al.,* 1987, Lunstra *et al.,* 1988, Smith *et al.,* 1989, Kriese *et al.,* 1991, Moser *et al.,* 1996, Maiwashe *et al.,* 2002). Bulls with small testicles have reduced sperm production and seminal quality (Cates, 1975, Coulter and Foote, 1979, Roa Veeramachaneni *et al.,* 1986, Arteaga *et al.*, 2001, Kastelic *et al.*, 2001). These were important findings, since heritability estimates of semen traits are generally low (Pearson *et al.,* 1984, Smith *et al.,* 1989).

Scrotal circumference has been found to be a good indicator of age of puberty in young bulls (Lunstra, 1982, Brinks 1994, Brito *et al.*, 2004, Torres-Junior and Henry, 2005) and age of puberty in half-sibling heifers (Brinks *et al.,* 1978, King *et al.,* 1983, Toelle and Robinson, 1985). These findings led Brinks to conclude that the magnitude of these relationships indicates that age of puberty in the female and scrotal circumference in the bull may be essentially the same trait.

As most beef bulls in Southern Africa are used for natural service, the environment and management practices often affect bull fertility. Most of the environmental and management factors that can, and often do, diminish the inherent seminal quality of a bull are mediated through either hormonal or

temperature-sensitive mechanisms. Exposure of the testes and epididymis to a minor but prolonged insult can often have a detrimental effect on seminal quality (Coulter, 1994. Ellis *et al.*, 2005). Nutrition is an environmental effect that may have prolonged effects in bull fertility. Diets adequate in protein, vitamins, minerals and energy appear to hasten the onset of puberty in beef bulls (Abdel-Raouf, 1960, Flipee and Almquist, 1961, Parkinson, 2004). However, Coulter (1994) and Coulter *et al.* (1997) are adamant that the feeding of high energy diets to post-pubertal beef bulls is of no benefit to reproductive capacity including seminal quality and may cause substantial harm to reproductive potential. Furthermore, Coulter (1988) hypothesized that a potential cause of this problem was the impairment of thermoregulation of scrotal contents due to insolative effects of scrotal fat or deposition of fat around the pampiniform plexus of the testicles.

Information on the effect of level of energy in the diet during intensive and semi-intensive feeding of young bulls (similar to feedlot) is limited. Based on preliminary work on Hereford bulls, Skinner (1981) demonstrated that fertility is severely compromised when high energy diets are fed for a prolonged period of time. He further speculated that the effect could be even greater in young bulls. Beef cattle producers and performance testing schemes utilize high dietary energy levels to finish bulls and performance test bulls in South Africa. Feeding high energy diets to bulls has been reported (Gillespie, 1983), to have a favourable effect on the expression of genetic potential for growth rate in young bulls, on growth and carcass characteristics (Woody *et al.,* 1983) and on feed efficiency (Price *et al.,* 1984). However, it has also been

reported to reduce the reproductive potential of young bulls (Mwansa and Makarechian 1991, Coulter 1994).

The aim of this study was to determine if scrotal circumference and age are an accurate predictor of bull fertility and to measure the influence that high energy diets have on production and fertility traits in beef bulls fed different levels of energy.

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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 50×10^6 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 ($\times 10^9$)	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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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, Jiménez-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 84th 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)

VARIABLE	OLDER BULLS (OB)			YOUNGER BULLS (YB)			
	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 sperma-tozoa, 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.