

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 30° 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 brucellosis 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 (\pm 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 | \pm 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 ($^{\circ}$ 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 (\pm SEM) tick concentrations.

| Gender | n | Mean number of ticks | \pm 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 (\pm SEM) for the different age groups of cattle.

| Age (years) | n | Mean number of ticks | \pm 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 effector 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.

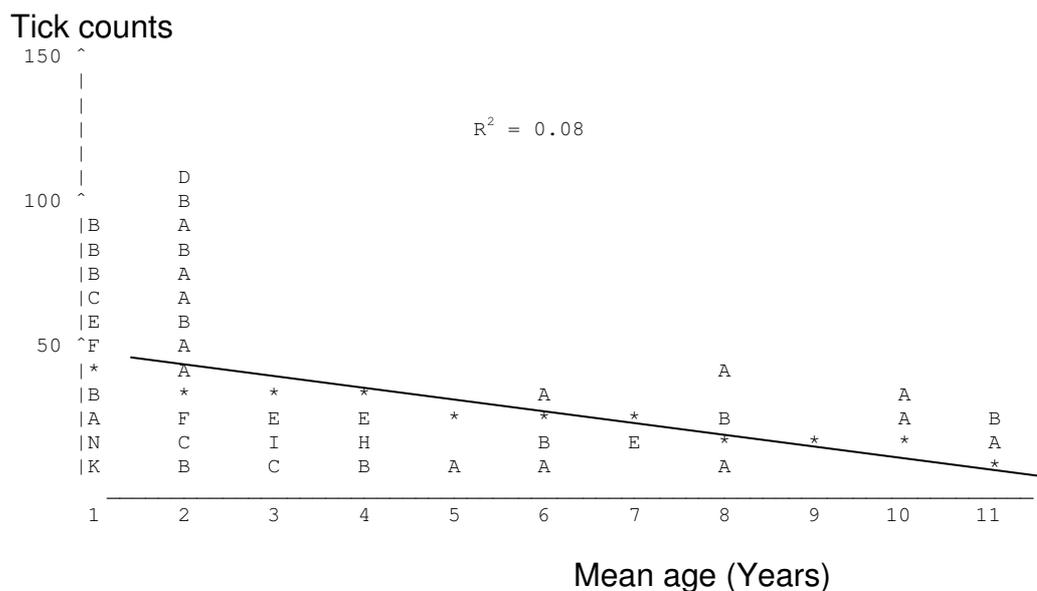


Figure 5.1 : The influence of age on the tick burdens observed in beef cattle.

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

| Body weight (kg) | n | Mean number of ticks | \pm 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 *zebu* 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.

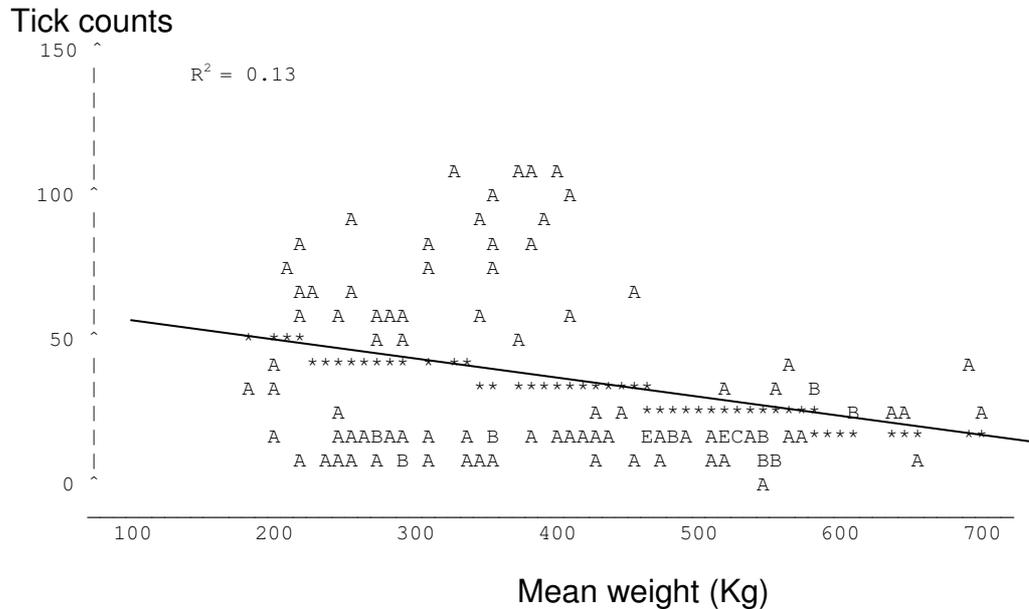


Figure 5.2 : The effect of weight on tick burdens observed on beef cattle.

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 (\pm SEM) for the different BCS of cattle.

| BCS (1-5) | n | Mean number of ticks | \pm 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 (\pm SEM) as affected by surface body temperature.

| Body Surface temperature ($^{\circ}$ C) | n | Mean number of ticks | \pm 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.

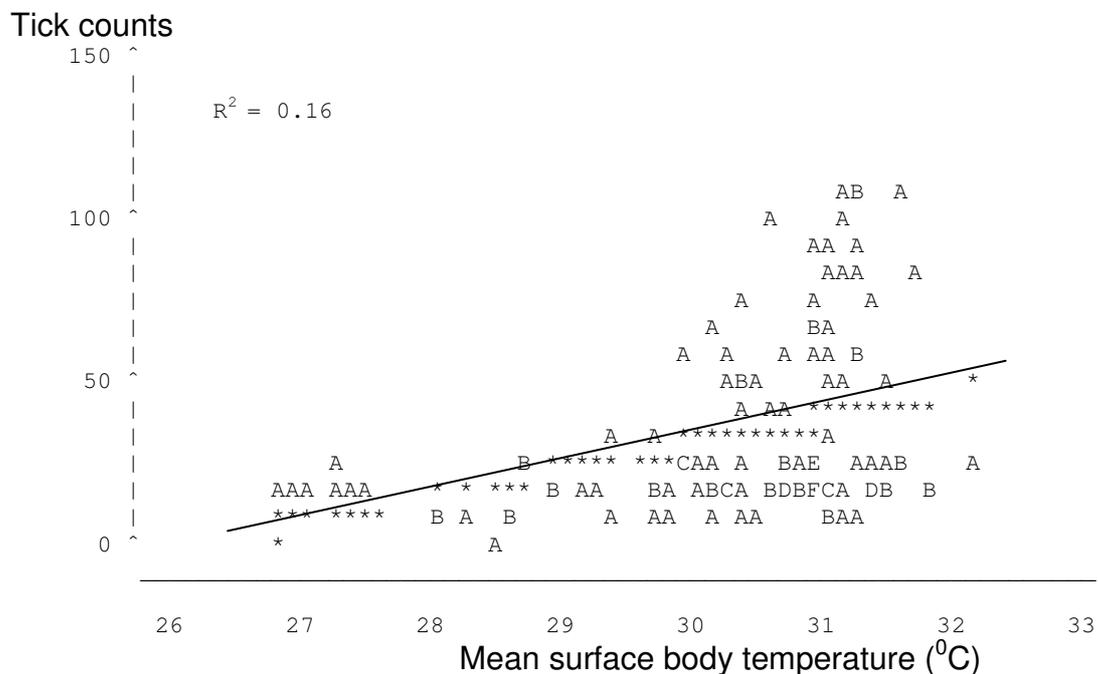


Figure 5.3 : The effect of body surface temperature on tick burdens observed on beef cattle.

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 (\pm SEM) for cattle at different ages.

| Age(years) | n | Mean Coat score (1-5) | \pm 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.

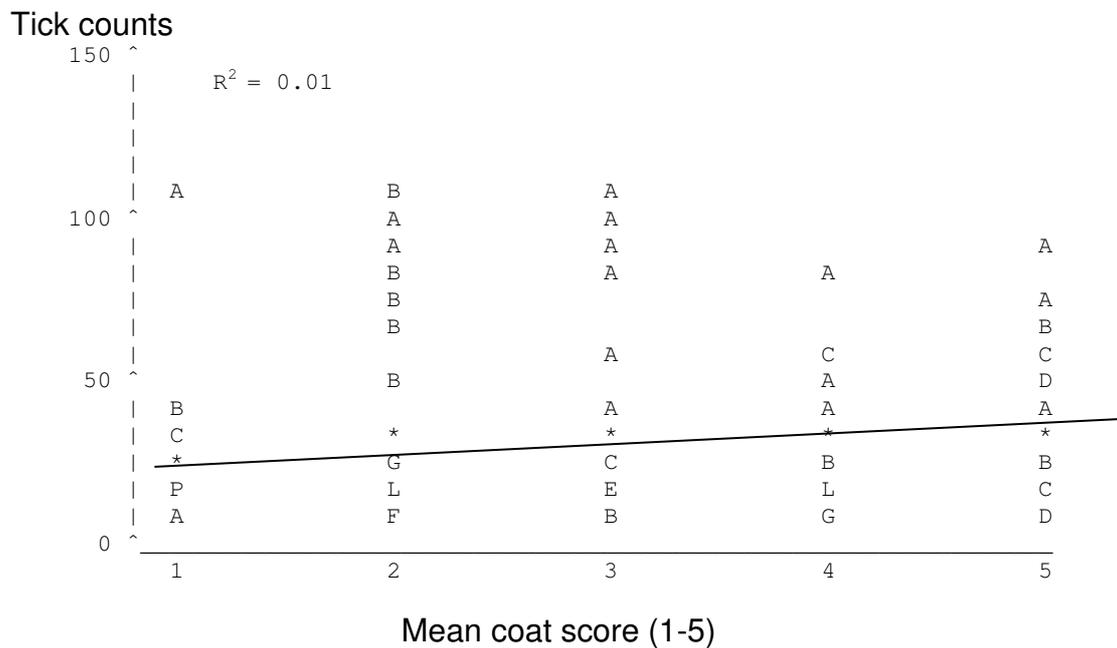


Figure 5.4 : The effect of CS on tick burdens observed on beef cattle.

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

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 (\pm SEM) for the different body heights of cattle.

| Height (cm) | n | Mean number of ticks | \pm 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 ($p < 0.05$)

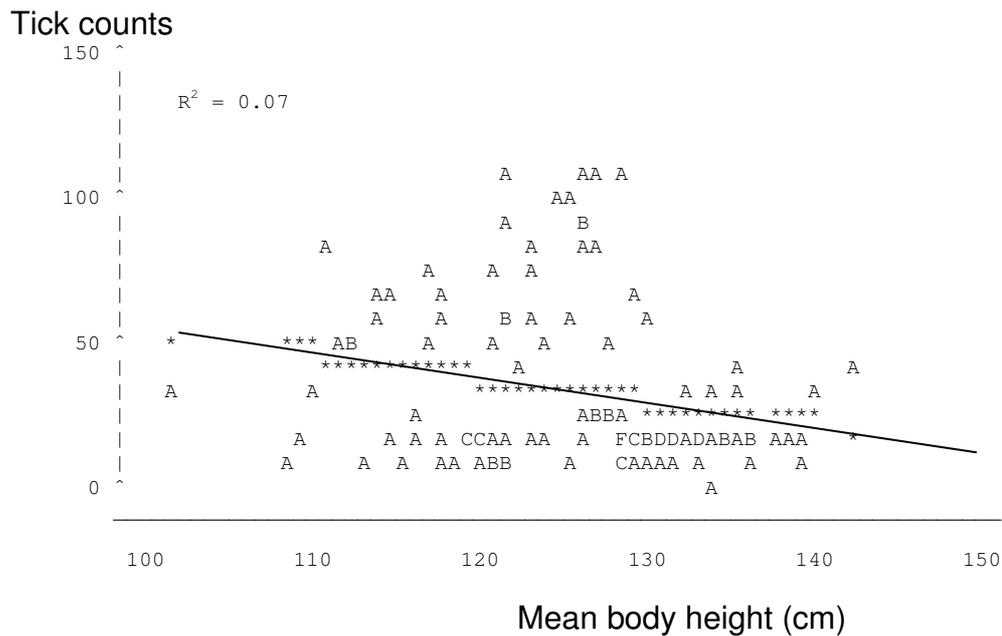


Figure 5.6 : The effect of body height on tick burdens observed on beef cattle.

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 (\pm SEM) for the different body lengths of cattle.

| Body length (cm) | n | Mean number of ticks | \pm 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

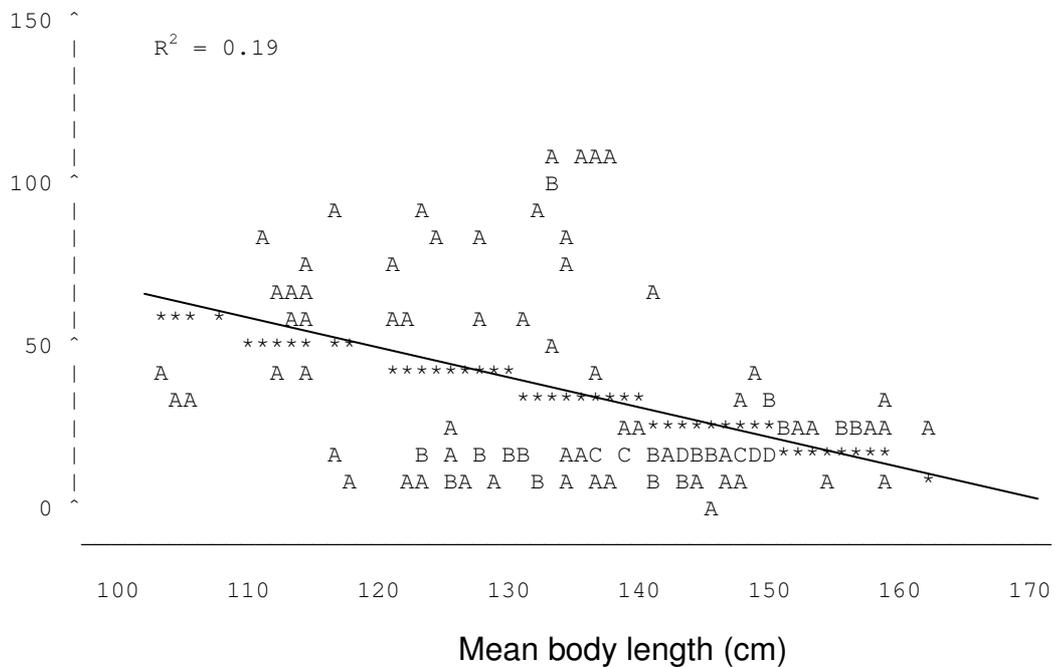


Figure 5.7 : The influence of body length on tick burdens observed on beef Cattle.

It is generally expected 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 (\pm SEM) for the different inter-calving period (ICP) of cattle.

| ICP(days) | n | Mean number of ticks | \pm 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 carries 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.

5.6 REFERENCES

AERTS, J. M., AND NESHEIM, O.N. (1999). Florida beef cattle external pest control survey. UF pesticide information office; Report in production. edis.ifas.ufl.edu/pdffiles/PI/PI04300.pdf

AMAKIRI, S.F. (1974). Seasonal changes in bovine skin thickness in relation to the incidence of *dermatophilus* infection in Nigeria. *Res. Vet. Sci*, 17, pp. 351 - 364.

BIANCHI, M.W., BARRE, N., AND MESSAD, S. (2003). Factors related to cattle infestation level and resistance to acaricides in boophilus microplus tick populations in New Caledonia. *IAC-CIRAD, BP 25, Paita, New Caledonia. Vet. Parasitol.* 28,112(1-2),pp.75-89

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12581586&dopt=Abstract

BONSMA, J. (1980). Livestock production: A global approach. Cape Town: Tafelberg.

BONSMA, J.C. (1981). Breeding tick repellent cattle. In: Whitehead, G.B. & Gibson, J.D. (Eds). Proceedings of an International Conference on Tick Biology and Control, 27-29 January 1981, Rhodes University, Grahamstown, South Africa, p. 67.

BROSSARD, M. (1998). The use of vaccines and genetically resistant animals in tick control. *Rev. Sci. tech. Off. Int. Epiz.* 17, pp. 188 - 196.

BROWN, S.J. (1984). Effect of host age on the expression of acquired resistance to ticks. *Experen.* 40, pp. 199 - 212.

CORBET, N.J., SHEPHERD, R.K., BURROW, H.M., VAN DER WESTHUIZEN, J., STRYDOM, P.E., AND BOSMAN, D.J. (2006). Evaluation of Bonsmara and Belmont Red cattle breeds in South Africa. 1. Productive performance. *Aust. J. Exp. Agric.* 46, pp.199 - 212.

DE CASTRO, J.J., AND NEWSON, R.M. (1993). Host resistance in cattle tick control. *Parasitol. Today.* 9, pp. 13 - 16.

DOUBE, B.M., AND WHARTON, R.H. (1980). The effect of locality, breed and previous tick experience on seasonal changes in the resistance of cattle to *Boophilus microplus* (Ixodoidea: Ixodidae). *Experen.* 36, pp. 1178 - 1188.

ERVIN, R.T., EPPLIN, F.M., BYFORD, R.L., AND HAIR, J.A. (1987). Estimation and economic implications of lone star tick (*Acari: Ixodidae*) infestation on weight gain of cattle, *Bos taurus* and *Bos taurus x Bos indicus*. *J. Econ. Entomol.* 80, pp. 443 - 455.

EISLER, M.C., TORR, S.J., COLEMAN, P.G., MACHILA, N., AND MORTON, J.F. (2003). Integrated control of vector-borne diseases of livestock-pyrethroids: panacea or poison? *Trends in Parasitology*. 19, 341-5. <http://www.nri.org/tsetse/FAQ/Pdf/torr02.pdf>

FINCH, V.A., BENNET, I.L., AND HOLMES, C.R. (1984). Coat colour in cattle: effect on thermal balance, behaviour and growth, and relationship with coat type. *J. Agric. Sci., Cambridge*. 102, pp. 141 - 157.

FOIL, L.D, COLEMAN, P., EISLER, M., FRAGOSO-SANCHEZ, H., GARCIA-VAZQUEZ, Z., GUERRERO, F.D., JONSSON, N.N., LANGSTAFF, I.G., LI, A.Y., MACHILA, N., MILLER, R.J., MORTON, J., PRUETT, J.H., AND TORR, S. (2004). Factors that influence the prevalence of acaricide resistance and tick-borne diseases. *Vet parasitol*. 28: 125(1-2), pp. 163 - 181.

FRANCIS, J., AND LITTLE, D.A. (1964). Resistance of Drought master cattle to tick infestation and *babesiosis*. *Aust. Vet. J.* 40, pp. 247 - 258.

FRISCH, J.E., AND O'NEIL, C.J.O. (1998). Comparative evaluation of beef cattle breeds of African, European and Indian origins. 2. Resistance to cattle ticks and gastrointestinal nematodes. *Anim. Sci.* 67, pp. 39 - 47.

FRISCH, J.E., AND VERCOE, J.E. (1984). An analysis of growth of different cattle genotypes reared in different environments. *J. Agric. Sci., Cambridge*. 103, pp. 137 - 147.

FRISCH, J.E. (1999). Towards a permanent solution for controlling cattle ticks. *International J. Parasitol.* 29, pp. 57 - 68.

FRISCH, J.E., O'NEIL, C.J., AND KELLY, M.J. (2000). Using genetics to control cattle parasites- the Rockhampton experience. *International J. Parasitol.* 30, pp. 253 - 266.

GAUGHAN, J.B., MADER, T.L., HOLT, S.M., JOSEY, M.J., AND ROWAN, K.J. (1999). Heat tolerance of Boran and Tuli crossbred steers. *J. Anim. Sci.* 77, pp. 2398 - 2405.

GARCIA, M., HUANCA, W., AND CHÁVEZ, A. (1989). Body weight, tick burden (*Boophilus microplus*), physiological parameters and reproductive efficiency of crossbred Zebu cattle. *Acta Vet. Scan.* 30, pp. 347 - 459.

GEORGE, J.E., OSBURN, R.L., AND WIKEL, S.K. (1985). Acquisition and expression of resistance by *Bos indicus* and *Bos indicus* x *Bos taurus* calves to *Amblyomma americanum* infestation. *J. Parasitol.* 71, pp. 174 - 186.

GERTENBACH, W. (2001). Farming with ticks: a Herd management approach. Internet URL <http://www.sasas.co.za/>.

GLADNEY, W.J., GRAHAM, O.H., TREVINO, J.L., AND ERNST, S.E. (1973). *Boophilus annulatus*: effect of host nutrition on development of female ticks. *J. Med. Entomol.* 10, pp. 123 - 132.

GUERRERO, J. (1987). The economic effect of parasite control programs in beef cattle at different stages of development. In: W.H.D. Leaning & J. Guerrero (eds.), Economic impact of parasitism in cattle. Proceedings MSD AGVET Symposium, XXXIII World Veterinary Learning Systems Company, Lawrenceville, N.J. pp. 99 – 106.

HAYMAN, R.H., BEESTON, J.W.U., ALLEN, T.E., AND NAY, T. (1966). Skin thickness in Sahiwal and Jersey cattle and its measurements. *J. Agric. Sci.* 67, pp. 345 - 357.

JONSSON, N.N., MAYER, D.G., MATSCOSS, A.L., GREEN, P.E., AND ANSELL, J. (1998). Production effects of the cattle tick (*Boophilus microplus*) infestation on high yielding dairy cows. *Vet. Parasitol.* 78, pp. 65 - 76.

JUTZI, S.C. (2003). Food safety: Challenges and opportunities facing production of livestock and livestock products. Pan American health organization. world health organization, 13th inter-American meeting, at the ministerial level, on health and agriculture Washington, D.C., 24–25 April. www.paho.org/English/AD/DPC/VP/rimsa13-11-e.pdf

KLEINDORFER, S., LAMBERT, S., AND PATON, D.C. (2006). Ticks (*Ixodes* sp.) and blood parasites (*Haemoproteus* spp.) in New Holland honeyeaters (*Phylidonyris novaehollandiae*): evidence for site specificity and fitness costs. *Emu. Austral. Ornithology.* 106:2.
<http://www.publish.csiro.au/paper/MU05055.htm>

LEHMANN, T. (1993). Ecto-parasites: Direct impact on host fitness. *Parasitol. Today.* 9, pp. 8 - 17.

LIMA, W.S., RIBEIRO, M.F., AND GUIMARAES, M.P. (2000). Seasonal variation of *Boophilus microplus* (Canestrini, 1887) (*Acari: Ixodidae*) in cattle in Minas Gerais State, Brazil. *Trop. Anim. Hlth. Prod.* 32, pp. 375 - 387.

MAIWASHE, A.N., BRADFIELD, M.J., THERON, H.E., AND VAN WYK, J.B. (2002). Genetic parameter estimates for body measurements and growth traits in South African Bonsmara cattle. *Livestock Prod. Sci.* 75, pp. 293 - 302.

MAREE, C., AND CASEY, N.H. (1993). Livestock production systems: Principles and Practice. Book Productions, Pretoria. p.19.

MATTIOLI, R.C., PANDEY, V.S., MURRAY, M., AND FITZPATRICK, J.L. (2000). Immunogenetic influences on tick resistance in African cattle with particular reference to trypanotolerant N'Dama (*Bos taurus*) and trypanosusceptible Gobra zebu (*Bos indicus*) cattle. *Acta Tropica* 75, pp. 263 – 277.

MINJAUW, B., AND MCLEOD, A. (2003) Tick-borne diseases and poverty; the impact of ticks and tick-borne disease on the livelihoods of small-scale and marginal livestock owners in India and eastern and southern Africa. Roslin: University of Edinburgh, Centre for Tropical Veterinary Medicine, DFID Animal Health Programme. pp. 116 – 123.

MOORING, M.S., MAZHOWU, W., AND SCOTT, C.A. (1994). The effect of rainfall on tick challenge at Kyle Recreational Park in Zimbabwe. *Experimen. and Appl. Acar.* 18, pp. 507 - 515.

NAY, T., AND HAYMAN, R.H. (1963). Some skin characters in five breeds of European (*Bos taurus L.*) dairy cattle. *Aust. J. Agric. Res.* 14, pp. 294 - 305.

NORVAL, R.A.I., SUTHERST, R.W., JORGENSEN, O.G., GIBSON, J.D., AND KERR, J.D. (1989). The effect of the Bont tick (*Amblyomma Hebraeum*) on the weight gain of Afrikaner steers. *Vet. Parasitol.* 33, pp. 329 - 337.

NORVAL, R.A.I., SUTHERST, R.W., KURKI, J., GIBSON, J.D., AND KERR, J.D. (1988). The effect of the Brown ear-tick *Rhipicephalus appendiculatus* on the growth of *Sanga* and European breeds of cattle. *Vet. Parasitol.* 30, pp. 149 - 155.

O' KELLY, J.C., AND KENNEDY, P.M. (1981). Metabolic changes in cattle due to the specific effect of the tick, *Boophilus microplus*. *The British J. Nutri.* 45, pp. 557 - 566.

O' KELLY, J.C., AND SPIERS, W.G. (1983). Observations on body temperature of the host and resistance to the tick *Boophilus microplus* (*Acari: Ixodidae*). *J. Med. Entomol.* 20, pp. 498 - 508.

O'KELLY, J.C., AND SEIFERT, G.W. (1969). Relationships between resistance to *Boophilus microplus*, nutritional status, and blood composition in Shorthorn X Hereford cattle. *Aust. J. Biol. Sci.* 22, pp. 1497 - 1509.

OLSON, T.A., LUCENA, C., CHASE, C.C., AND HAMMOND, A.C. (2003). Evidence of a major gene influencing hair length and heat tolerance in *Bos taurus* cattle. *J. Anim. Sci.* 81, pp. 80 – 90.

O'ROURKE, P.K. (1982). Reliability of tick counts and the relationship between tick count and live weight change in growing *Bos indicus* x *Bos taurus* cattle. In 'Animal Production in Australia'. *Proc. Aust. Soc. Anim. Prod.* 14, pp. 305 - 315.

OSORO, K., AND WRIGHT, I.A. (1992). The effect of body condition, live weight, breed, age, calf performance and calving date on reproductive performance of spring-calving beef cows. *J. Anim. Sci.* 70, pp. 1661 - 1676.

PRAYAGA, K. C. (2003). Evaluation of beef cattle genotypes and estimation of direct and maternal genetic effects in a tropical environment. 2. Adaptive and temperament traits. *Aust. J. of Agric. Res.* 54(10), pp. 1027-1038.

PEGRAM, R.G., LEMCHE, J., CHIZYUKA, H.G.B., SUTHERST, R.W., FLOYD, R.B., KERR, J.D., AND MCCOSKER, J.P. (1989). Effect of tick control on live weight gain in central Zambia. *Med. Vet. Entomol.* 3, pp. 313 - 320.

RECHAV, Y. (1992). Naturally acquired resistance to ticks- A global view. *Ins. Sci. and its Appl.* 13, pp. 495 - 510.

RIEK, R.F. (1956). Factors influencing the susceptibility of cattle to tick infestation. *Aust. Vet. J.* 32, pp. 204 - 217.

RIEK, R.F. (1962). Studies on the reactions of animals infested with ticks: VI. Resistance of cattle to infestation with the tick *Boophilus microplus*. *Aust. J. Agric. Res.* 13, pp. 532 - 546.

SAS, (2000). SAS/ STAT Users Guide, Volume 2, Version 8

SCHOLTZ, M.M., LOMBARD, P.E., DE BRUIN, D.S., ENSLIN, C.B., AND SPICKETT, A.M. (1989). Eenvoudige metode vir die beraming van bosluisbestandheid by beeste. *S. Afri. J. Anim. Sci.* 19, pp. 121 - 136.

SCHOLTZ, M.M., SPICKETT, A.M., LOMBARD, P.E., AND ENSLIN, C.B. (1991). The effect of tick infestation on the productivity of cows of three breeds of cattle. *Onderstepoort J. Vet. Res.* 58, pp. 71 - 80.

SEEBECK, R.M., SPRINGELL, P.H., AND O' KELLY, J.C. (1971). Alterations in host metabolism by the specific and anorectic effects of the cattle tick (*Boophilus microplus*). I. Food intake and body weight growth. *Aust. J. Biol. Sci.* 24, pp. 373 - 385.

SOLOMON, G., AND KAAAYA, G.P. (1998). Development, reproductive capacity and survival of *Amblyomma variegatum* and *Boophilus decoloratus* in relation to host resistance and climatic factors under field conditions. *Vet. Parasitol.* 75, pp. 241 - 252.

SOUTH AFRICAN WEATHER BUREAU. (2001). Personal Communication.

SPRINGELL, P.H. (1974). The cattle tick in relation to animal production in Australia. *World Anim. Rev.* 10, pp. 19 - 30.

SUTHERST, R.W., MAYWALD, G.F., KERR, J.D., AND STEGEMAN, D.A. (1983). The effect of cattle tick (*Boophilus microplus*) on the growth of *Bos indicus* x *Bos taurus* steers. *Aust. J. Agric. Res.* 34, pp. 317 - 329.

SUTHERST, R.W., NORTAN, G.A., BARLON, N.D., CONWAY, G.R., BIRLEY, M., AND COMINS, H.N. (1979). An analysis of management strategies for cattle tick (*Boophilus microplus*) control in Australia. *J. Appl. Ecol.* 16, pp. 259 - 267.

TAYLOR, G.J., SWANEPOEL, F.J.C., AND BISHOP, J. (1995). Factors influencing coat type in Bonsmara cattle. Proceedings of the 34th Annual Congress on Advances and Applications of Animal Science in South Africa, 10-13 April 1995, University of the Orange Free State, Bloemfontein, South Africa, pp. 69.

TEEL, P.D., FUCHS, T.W., HUSTON, J.E., LONGNECKER, M.T., AND PICKEL, S.L. (1990). Effects of sequential infestations of *Dermacentor albipictus* and *Amblyomma americanum* (Acari: Ixodidae) on over wintering beef cows in West-Central Texas. *J. Med. Entomol.* 27, pp. 632 - 652.

TURNER, H.G., AND SCHLEGER, A.V. (1960). The significance of coat type in cattle. *Aust. J. Agric. Res.* 11, pp. 645 - 652.

TURNER, H.G. (1962). Effect of clipping the coat on performance of calves in the field. *Aust. J. Agric. Res.* 13, pp. 180 - 192.

UTECH, K.B.W., AND WHARTON, R.H. (1982). Breeding for resistance to *Boophilus Microplus* in Australian Illawarra Shorthorn and Brahman x Australian Illawarra Shorthorn Cattle. *Aust. Vet. J.* 58, pp.41 - 53.

UTECH, K.B.W., WHARTON, R.H., AND KERR, J.D. (1978). Resistance to *Boophilus microplus* (Canestrini) in different breeds of cattle. *Aust. J. Agric. Res.* 29, pp. 885 - 897.

WAMBURA, P.N., GWAKISA, P.S., SILAYO, R.S., AND RUGAIMUKAMU, E.A. (1998). Breed- associated resistance to tick infestation in *Bos indicus* and their crosses with *Bos taurus*. *Vet. Parasitol.* 77, pp. 63 - 72.

WEBB, E.C., AND DAVID, M. (2001). The efficacy of neem seed extract (*Azadirachta indica*) to control tick infestation in Tswana, Simmentaler and Brahman cattle. *S. Afr. J. Anim. Sci.* 32, pp. 1 - 15.

WIKEL, S.K. (1999). Tick modulation of host immunity: an important factor in pathogen transmission. *Int. J. Parasitol.* 29, pp. 851 – 859.

WIKEL, S.K. (1996). Host immunity to ticks. *Annu Rev Entomol.* 41, pp.1 – 22.

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, Freedden *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, Flippee 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 insulative 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.

6.2 REFERENCES

ABDEL-RAOUF, M. (1960). The postnatal development of the reproductive organs in bulls with special reference to puberty. *Copenh. Acta Endocrinology (Suppl)* 49 (9).

ARTEAGA, A., BARACALDO, M., AND BARTH, A.D. (2001). The proportion of beef bulls in western Canada with mature spermograms at 11 to 15 months of age. *Can. J. Vet. Sci.* 42. pp 783 – 787.

BELLOWS, R.A., AND SHORT, R.E. (1994). Reproductive losses in the beef industry. In: M. J. Field and R. S. Sand (Ed.) *Factors Affecting Calf Crop*. CRC Press, Boca Raton, FL. pp. 109 - 133.

BELLOWS, R.A., AND STAIGMILLER, R.B. (1994). Selection for fertility. In: M. J. Field and R. S. Sand (Ed.) *Factors Affecting Calf Crop*. CRC Press, Boca Raton, FL. pp. 197 - 212.

BOURDON, R.M., AND BRINKS, J.S. (1986). Scrotal circumference in yearling Hereford bulls: Adjustment factors, heritabilities and genetic environmental and phenotypic relationships with growth traits. *J. Anim. Sci.* 62, pp. 958 - 968.

BRINKS, J.S. (1994). Relationships of scrotal circumference to puberty and subsequent reproductive performance in male and female offspring. In: M. J. Field and R. S. Sand (Ed.) *Factors Affecting Calf Crop*. CRC Press, Boca Raton, FL. pp. 363 - 370.

BRINKS, J.S. (1989). Genetics of reproductive traits in bulls. *Agri. Practice* 10, p 9.

BRINKS, J.S., MCINERNEY, M.J., AND CHENOWETH, P.J. (1978). Relationship of age at puberty in heifers to reproductive traits in young bulls. *Proc. West. Sect. Am. Soc. Anim. Sci.* 29, pp. 28 - 37.

BRITO, L.F.C., SILVA, A.E.D.F., UNANIAN, M.M., DODE, M.A.N., BARBOSA, R.T., AND KASTELIC, J.P. (2004). Sexual development in early- and late-maturing *Bos indicus* and *Bos indicus* x *Bos taurus* crossbred bulls in Brazil. *Theriogenology*. 62, pp. 1198 – 1217.

CATES, W.F. (1975). Observations on scrotal circumference and its relationship to classification of bulls. *Prov. Ann. Mt. Soc. Theriogenology*.. Cheyenne, WY. pp. 9 – 17.

CHACON, J., PEREZ, E., MULLER, E., SODERQUIST, L., AND RODRIGUEZ-MARTINEZ, H. (1999). Breeding soundness evaluation of extensively managed bulls in Costa Rica. *Theriogenology* 52, pp. 221 – 231.

CHENOWETH, P.J. (1981). Libido and mating behaviour in bulls, boars and rams. A review. *Theriogenology* 16, pp.155 - 169.

COOK, R.B., COULTER, G.H., AND KASTELIC, J.P. (1994). The testicular vascular cone, scrotal thermoregulation, and their relationship to sperm production and seminal quality in beef bulls. *Theriogenology* 41(3), pp. 653 – 671.

COULTER, G.H. (1988). Thermography of bull testis. *Proc. 12th Tech. Conf. A.I. Reprod.* p. 58.

COULTER, G.H. (1994). Beef bull fertility: Factors effecting seminal quality: Factors affecting calf crop. Edited by Fields, M.J. and Sand, R.S. Butterworths ISBN: 0-8493-8754-X. 12 , pp. 307 - 317.

COULTER, G.H., CARRUTHERS, T.D., AMANN, R.P., AND KOZUB, G.C. (1987). Testicular development, daily sperm production and epididymal sperm reserves in 15-month-old Angus and Hereford bulls: Effect of bull strain plus dietary energy. *J. Anim. Sci.* 64, pp. 254 - 265.

COULTER, G.H., COOK, R.B., AND KASTELIC, J.P. (1997). Effects of dietary energy on scrotal surface temperature, seminal quality, and sperm production in young beef bulls. *J. Anim. Sci.* 75, pp. 1048 - 1052.

COULTER, G.H., AND FOOTE, R.H. (1979). Bovine testicular measurement as indicators of reproductive performance and their relationship to productive traits in cattle. A review: *Theriogenology* 11, pp. 297 - 310.

DEJARNETTE, J.M., MARSHALL, C.E., LENZ, R.W., MONKE, D.R., AYARS, W.H., AND SATTLER, C.G. (2004). Sustaining the fertility of artificially inseminated dairy cattle: The role of the artificial insemination industry. *J. Dairy Sci.* 87, pp. 93 - 104

DU PLESSIS, I., HOFFMAN, L.C., AND CALITZ, F.J. (2005). The influence of production traits and pre-weaning growth rate on herd efficiency of different beef breed types in an arid sub-tropical environment. *S. Afri. J. Anim. Sci.* 35(2), pp. 89 – 98.

ELLIS, R.W., RUPP, G.P., CHENOWETH, P.J., CUNDIFF, L.V., AND LUNSTRA, D.D. (2005). Fertility of yearling beef bulls during mating. *Theriogenology*. 64, pp. 657 – 678.

FITZPATRICK, L.A., FORDYCE, G., MCGOWAN, M.R., BERTRAM, J.D., DOOGAN, V.J., DE FAVERI, J., MILLER, R.G., AND HOLROYD, R.G. (2002). Bull selection and use in northern Australia. Part 2. Semen traits. *Anim. Reproduction Sci.* 71, pp. 39 – 49.

FLIPEE, R.J., AND ALMQUIST, J.O. (1961). Effect of total digestible nutrient intake from birth to four years of age in growth and reproductive development and performance of dairy bulls. *J. Dairy. Sci.* 44, pp. 905 - 1010.

FREDEEN, H.T., WEISS, G.M., RAHNEFELD, G.W., LAWSON, J.E., AND NEWMAN, J.A. (1987). Beef cow reproduction in relation to cow weight and condition. *Can-Man. Econ. Reg. Dev. Agree. Tech. Bull.* No.12101.3.

GILLESPIE, R.J. (1983). Modern livestock and poultry production. Delmar Publisher Inc., Albany, New York. p. 156.

GODFREY, R.W., AND LUNSTRA, D.D. (1989). Influence of single or multiple sires and serving capacity on mating behaviour of beef bulls. *J. Anim. Sci.* 67, pp. 2897 - 2913.

GREER, R.C., WHITMAN, R.W., AND WOODWARD, R.R. (1980).

Estimation of probability of beef cows being culled and calculation of expected herd life. *J. Anim. Sci.* 51 (10), pp. 857 – 868.

HOLROYD, R.G., BERTRAM, J.D., DOOGAN, V.J., FORDYCE, G., PETHERICK, J.C., AND TURNER, L.B. (2004). Breeding soundness of sale

bulls after relocation. In: Bull power: Delivery of adequate normal sperm to the site of fertilisation. Project report NAP3.117, Meat and Livestock Australia, Sydney. pp. 11 – 22.

KASTELIC, J.P., COOK, R.B., PIERSON, R.A., AND COULTER, G.H.

(2001). Relationship among scrotal and testicular characteristics, sperm production, and seminal quality in 129 beef bulls. *Can. J. of Vet. Research.* 65, pp. 111 - 115

KENNEDY, S.P., SPITZER, J.C., HOPKINS, H.L., HIGDON, H.L., AND BRIDGES, W.C. (2002). Breeding soundness evaluation of 3648 yearling

beef bulls using the 1993 Society for Theriogenology guidelines. *Theriogenology.* 58, pp. 947 – 961.

KING, R.G., KRESS, D.D., ANDERSON, D.C., DOORNBOS, D.E., AND BURFENING, P.J. (1983). Genetic parameters in Herefords for puberty in

heifers and scrotal circumference in bulls. *Proc. West. Sect. Am. Soc. Anim. Sci.* 34, p.11.

KRIESE, L.A., BERTRAND, J.K., AND BENYSHEK, L.L. (1991). Age adjustment factors, heritabilities and genetic correlations for scrotal circumference and related growth traits in Hereford and Brangus bulls. *J. Anim. Sci.* 69, pp. 478 - 489.

LUNSTRA, D.D. (1982). Testicular development and onset of puberty in beef bulls. In beef Research Program Progress Report no. 1, U.S. Meat animal Research Centre ARMM-NC-21. p. 26.

LUNSTRA, D.D., GREGORY, K.E., AND CUNDIFF, L.V. (1988). Heritability estimates and adjustment factors for the effect of bull age and age of dam on yearling testicular size in breeds of bulls. *Theriogenology*, 30, pp 127 - 139.

MAIWASHE, A.N., BRADFIELD, M.J., THERON, H.E., AND VAN WYK, J.B. (2002). Genetic parameter estimates for body measurements and growth traits in South African Bonsmara cattle. *Livestock Prod. Sci.* 75, pp. 293 – 300.

MAKARECHIAN, M., FARID, A., AND BERG, R.T. (1983). Studies on natural service fertility of yearling bulls in multiple sire matings. Agriculture and forestry bulletin, University of Alberta, pp. 10 – 12 (CAB abstract).

McGOWAN, M.R., BERTRAM, J.D., FORDYCE, G., FITZPATRICK, L.A., MILLER, R.G., JAYAWARDHANA, G.A., DOOGAN, V.J., DE FAVERI, J., AND HOLROYD, R.G. (2002). Bull selection and use in Northern Australia. 1. Physical traits. *Animal reproduction Science*. 71, pp. 25 – 37.

MOSER, D.W., BERTRAND, J.K., BENYSHEK, L.L., McCANN, M.A., AND KISER, T.E. (1996). Effects of selection for scrotal circumference in Limousin bulls on reproductive and growth traits of progeny. *J. Anim. Sci.* 74, pp. 2052 – 2057.

MWANSA, P.B., AND MAKARECHIAN, M. (1991). The effect of post-weaning level of dietary energy on sex drive and semen quality of young beef bulls. *Theriogenology*. 35, pp. 619 - 628.

PALASZ, A.T., CATES, W.F., BARTH, A.D., AND MAPLETOFT, R.J. (1994). The relationship between scrotal circumference and quantitative testicular traits in yearling bulls. *Theriogenology*. 42, pp. 715 - 726.

PARKINSON, T.J. (2004). Evaluation of fertility and infertility in natural service bulls. *The Veterinary Journal*. 168, pp. 215 – 229.

PEARSON, R.E., ERNST, C.A., SAACKE, R.G., AND BAME, J.H. (1984). Heritability and repeatability; preliminary estimates of bulls entering progeny test programs and example of how to use the parameters, *Prov. Tenth. Conf. A.I. Reprod. Ins. Training. Conf. N.A.A.B.*, Columbia. pp. 4.

PRICE, M.A., BUTSON, S., AND MAKARECHIAN, M. (1984). The influence of energy level on growth and carcass traits in bulls of two breeding types. *Can. J. Anim. Sci.* 64, pp. 323 – 332.

ROA VEERAMACHNENI. D.N., OTT, R.S., HEATH, E.H., MCENTEE, K., BOLT, D.J., AND HIXON, J.E. (1986). Pathophysiology of small testes in beef bulls: relationship between scrotal circumference Histopathologic features of testes and epididymis, seminal characteristics and endocrine profiles. *Am. J. Vet. Res.* 47, pp. 1988 - 1997.

SKINNER, J.D., 1981. Nutrition and fertility in pedigree bulls. In: Environmental factors in mammal reproduction. Eds. Desmond, Gilmore and Cook. Macmillan, London, pp 160-168.

SMITH, B.A., BRINKS, J.S., AND RICHARDSON, G.V. (1989). Estimation of genetic parameters among breeding soundness examination components and growth traits in yearling bulls. *J. Anim. Sci.* 67, pp. 2892 - 2911.

TOELLE, V.D., AND ROBINSON, O.W. (1985). Estimates of genetic correlations between testicular measurements and female reproductive traits in cattle. *J. Anim. Sci.* 60, pp. 89 - 101.

TORRES-JUNIOR, J.R.S. AND HENRY, M. (2005). Sexual development of Guzerat (*Bos taurus indicus*) bulls raised in a tropical region. *Anim. Reprod.* 2. pp. 114 – 121.

TRENKLE, A., AND WILHAM, R.L. (1977). Beef production efficiency. *Science.* 198, pp. 1009 - 1021.

WEIGEL, K.A. (2006). Prospects for improving reproductive performance through genetic selection. *Anim. Reproduction. Sci,* doi:10.1016/j.anireprosci.2006.08.010

WILLIAMS, G.L. (1988). Breeding capacity, behaviour and fertility of bulls with Brahman genetic influence during synchronized breeding of beef females. *Theriogenology.* 30, pp. 35 - 44

WOODY, H.D., FOX, D.G., AND BLACK, J.R. (1983). Effects of diet grain content on performance of growing and finishing cattle. *J. Anim. Sci.* 57, pp. 717 – 728.