EFFECT OF HEAT STRESS ON SIX BEEF BREEDS IN THE ZASTRON DISTRICT: THE SIGNIFICANCE OF BREED, COAT COLOUR AND COAT TYPE

By

Liesel Ann Foster

Thesis submitted in fulfilment of the requirements for the degree

Magister Technologiae:

Agriculture

at the

School of Agriculture and Environmental Sciences
Faculty of Health and Environmental Sciences

of the

CENTRAL UNIVERSITY OF TECHNOLOGY,
FREE STATE

Supervisor: Prof P.J. Fourie (D. Tech.)
Co-supervisor: Prof F.W.C. Neser (Ph.D)

BLOEMFONTEIN
January 2010

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EFFECT OF HEAT STRESS ON SIX BEEF BREEDS IN THE ZASTRON DISTRICT: THE SIGNIFICANCE OF BREED, COAT COLOUR AND COAT TYPE

SUMMARY

The objective of this study was to determine which parameters had the greatest response on a heifer's susceptibility to heat stress. Parameters tested were breed, coat colour, coat score, hide thickness, tick counts, weight gain, respiration rate and body condition score. The study was conducted in the south-eastern Free State. Afrikaner, Bonsmara, Braford, Charolais, Drakensberger and Simmentaler heifers were subject ted to a heat tolerance trial. A total of 60 heifers, 10 of each breed were evaluated. Rectal temperature (RT) was used as a parameter to determine heat stress. The heifers were evaluated on seventeen individual days, at 14:00 during the summer of 2007/8 (after being exposed to the sun for 1 hour with no access to shade). Significant differences in RT were measured on 13 occasions between breeds. The following factors had a significant influence ($P < 0.05$) on the rectal temperatures in the following breeds: Afrikaner – hide thickness, Bonsmara – hide thickness, Charolais – coat score. Coat colour, coat score, hide thickness, weight gain, respiration rate and body condition score did not have any significant influence on the RT of the Braford, Drakensberger and Simmentaler heifers. Hide thickness was found to be highly negatively correlated (-0.69) to tick count. Coat score was positively correlated to tick count (0.70) and weight gain (0.33). The correlation between coat score and body condition score was found to be negative (-0.40). The significance of the correlations was at a level of $P < 0.0001$. From the results of the present study it appeared that breed rather than factors such as coat colour, coat score, hide thickness, tick counts, body condition score, weight gain and respiration rate was a indicator whether a heifers would suffer from heat stress. It appeared that the Charolais and Simmentaler heifers were more prone to suffer from heat stress as these breeds had elevated rectal temperatures compared to the other breeds on hot days. It is recommended that farmers farm with the breed most adapted in that area.

EFFEK VAN HITTESTRES OP SES VLEISBEESRASSE IN DIE ZASTRON DISTRIK: DIE BELANG VAN RAS, HAAR KLEUR EN HAAR TIPE

OPSOMMING

Die doel van hierdie studie was om te bepaal watter faktore die grootste invloed op 'n vers se vatbaarheid vir hittestress gehad het. Parameters getoets was ras, haar kleur, haartipe, huiddikte, bosluitelling, gewigstoename, asemhalingstempo en kondisietelling. Die studie is in die suidoos Vrystaat gedoen. Afrikaner, Bonsmara, Braford, Charolais, Drakensberger en Simmentaler verse is aan hitte onderwerp.'n Totaal van 60 verse, 10 van elke ras is geëvalueer. Rektale temperature (RT) is gebruik as 'n maatstaf om hitteverdraagsaamheid te bepaal. Die verse oor sewentien geleenthede teen 14:00 ge-evalueer gedurende die somer van 2007/8 (na 1 h in die son, geen toegang tot skaduwee). 'n Betekenisvolle verskil in RT is op 13 geleenthede tussen rasse gemeet. Die volgende faktore het 'n betekenisvolle ($P < 0.05$) invloed op die rektale temperature van die volgende rasse gehad: Afrikaner – huiddikte, Bonsmara – huiddikte, Charolais – haartipe. Haar kleur, haartipe, huiddikte, bosluistelling, gewigstoename, asemhalingstempo en kondisietelling het geen beduidende invloed op die rektale temperature van die Braford, Drakensberger en Simmentaler verse gehad nie. Huiddikte was hoogs negatief gekoreleerd (0.69) met bosluistelling. Haar tipe was positief gekorreleerd met bosluistelling (0.70) en gewigstoename (0.33). Die korrelasie tussen haar tipe en kondisitelling was negatief (-0.40). Al die korrelasies was hoogs betekenisvol ($P < 0.0001$). Die resultate van die studie dui dat ras eerder as haar kleur, haar tipe, huiddikte, bosluistelling, gewigstoename, asemhalingstempo en kondisietelling 'n aanduiding is of 'n vers vatbaar sal wees vir hittestress. Dit wil voorkom of die Charolais en Simmentaler verse meer vatbaar is vir hittestress aangesien hulle meer geneig was om 'n verhoogde rektale temperatuur te hê op warm dae. Daar word aanbeveel dat boere met die ras boer wat die beste aangepas is in sy omgewing.

ACKNOWLEDGEMENTS

The author wishes to express her sincere gratitude and appreciation to the following persons and institutions:

- My supervisors, Prof. Frikkie Neser and Prof. Pieter Fourie. Without their continual encouragement, competent guidance and constructive criticism, this study would not have been possible.

- Dr. Mike Fair for the statistical analysis.

- National Research Foundation, Drakensberger Breeders' Society and CUT, Free State for financial support.

- My fellow farmers Mr. N van Rooyen, Mr. J Beeslaar, Mr E Heyns and Mr. F Wasserfall for providing the study animals.

- My mother, Mrs M Human, for assisting me in recording measurements and my husband , Mr R Foster, for his continued support and belief in my abilities.

Last but not least, I thank God for his unconditional guidance and providing me with the ability, strength and guidance to complete my study.

DECLARATION OF INDEPENDENT WORK

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

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LA Foster Date

LIST OF ABBREVIATIONS

°C	-	degree Celsius
AFR	-	Afrikaner
B	-	Brahman
B. indicus	-	*Bos indicus*
B. taurus	-	*Bos taurus*
BCS	-	body condition score
BFD	-	Braford
BON	-	Bonsmara
CHL	-	Charolais
CS	-	coat score
DRB	-	Drakensberger
E	-	environment
G	-	genotype
H	-	Hereford
HSRA	-	heat stress areas
LWSI	-	Livestock Weather Safety Index
mm	-	millimetre
$\mathbf{R_r}$	-	respiration rate
s.e.	-	standard error
SIM	-	Simmentaler
T	-	tick count
tdb	-	dry-bulb temperature
tdp	-	dew-point temperature
THI	-	Temperature Humidity Index
RT	-	rectal temperature
WMO	-	World Meteorological Organisation
β	-	regression coefficient

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction

It is well documented Maree & Casey, (1993) that the stress of hot environments lowers productive and reproductive efficiency in farm animals. Cattle grazing on natural pastures are often unable to escape from their environment and as a consequence they are candidates for heat stress. High temperatures raise the concern of heat stress on cattle. Heat stress is hard on livestock, especially in combination with high humidity. Hot weather and high humidity can reduce breeding efficiency, milk production, feed intake, weight gains, and sometimes cause death. Livestock should be observed frequently and producers should take precautions when hot and humid weather is forecasted.

Mammals have developed heat-regulating mechanisms that allow them to maintain, under everyday environmental conditions, a relatively constant deep-body temperature, independent of the immediate environment. For the maintenance of homeothermy, an animal must be in thermal equilibrium with its environment, which includes radiation, air temperature, air movement, and humidity. The total heat exchange of an animal occurs through radiation, convection, conduction, and evaporation and will vary with environmental conditions. Radiation exchange is important in the maintenance of thermal equilibrium. Radiant energy is received directly from the sun, as diffuse solar radiation due to atmospheric scattering, and by reflection from clouds and the ground surface. The orientation of the animal to the sun, and reflection and absorption characteristics of the coat, will also affect the balance of this radiant energy.

When the ambient temperature approaches or exceeds body temperature, the animal must escape, or increase its active cooling by evaporation of water from the respiratory tract or from the skin by sweating. The hair coats of cattle of different breeds vary from fine and glossy to thick and woolly, and present a range of insulation values; this will affect heat exchange by convection and evaporation of sweat. Williams *et al*. (2006) reported that sires whose progeny were slick haired had higher weaning weights and post weaning gains than progeny of non-slick sires. According to Olson *et al*. (2003) there were indications that the slick-haired calves grew faster immediately following weaning and that their growth during the cooler months of the year was not compromises significantly by their reduced quantity of hair.

November-March are the hottest months of the year with the highest monthly mean "temperature-humidity index" (THI) in South Africa and Namibia. These 5 months are associated with severe heat stress in cattle, are of critical importance for their performance and may have great economic implications for the owner as well as for the dairy industry. Not all parameters are trustworthy and practical to use as parameters to determine heat stress in cattle. The temperature-humidity index (THI) is still the best, simplest and most practical index (parameter) for measurement of environmental warmth which causes heat stress (Du Preez, 2000).

1.2 Motivation

There is probably no other agricultural sector were there is such a wide-ranging diversity of opinions and perspectives as in the beef industry in South Africa, being it at the level of the farmer or producer or at the level of the animal scientist. These differences are often about the choice of breed, production systems, breeding, supplementation, management, marketing and all sorts of other sentimentality (Mentz, 2002).

There are various reasons why such a wide variety of opinions and perspectives exist. One of the most significant reasons could be that there are hopelessly too many presumptions and philosophies without concrete evidence (Mentz, 2002). A causative component is that breed standards on which breed improvements are mainly based are not essentially founded on biological values; they are partly synthetic devises wanting scientific basis (Bonsma, 1983).

Amid all these presumptions and convictions the indigenous Sanga breeds and their derivatives endured a great blow (Mentz, 2002). In the past, these indigenous breeds were disregarded to such a great extent that they were not able to occupy their rightful place in the South African beef industry**.**

Climatic change and a shortage of water are inescapable. All indications point to the fact that the South Africa of the future is going to be a warmer and drier place. The farmer is in a position to cope with these eminent challenges, but only if he is prepared to learn to farm sustainably and in harmony with the environment. He will have to implement suitable production systems and farm with adapted breeds (Mentz, 2002). The main force responsible for selection in nature is the survival of the fittest in a particular environment. Nature tends to select against the weaker animals and only the strong survive to reproduce the species. In the long run natural selection leads to improved genetic acclimatisation to the prevailing environmental conditions (Du Preez, 2000).

Adaptability plays a vital role in sustainable commercial cattle farming. There is no doubt that the adaptability phenomenon exhibited by animals in unfavourable climates has a parallel in our domestic animals. Consequently, by applying our knowledge of the occurrence of adaptability, we can breed for adaptability in our domestic livestock without having to suffer losses, which a process of natural selection would have caused (Bonsma, 1983).

The interaction of genotype and environment (G x E) simply means that the effect of the environment on different genotypes is not the same. This indicates that there is no universally “best” genotype – the “best” genotype will differ from one environment to another depending on the prevalent environmental conditions (Verscoe & Frisch, 1990).

To the farmer G x E means using that particular breed of animal that is most productive in its environment. To the scientist it presents the venture of comprehending whether genetic or environmental changes are the most efficient avenues through which productivity can be enhanced. G x E is more consequential in extensive production systems since environmental variables such as nutrition, parasites, disease and climatic conditions cannot be closely controlled (Verscoe & Frisch, 1990).

G x E presents specific problems to the animal breeder as selection procedures directed at improving production in one environment may be counter-productive if the animals are to be used for breeding in diverse locations (Verscoe & Frisch, 1990).

Keeping livestock that are in harmony with the environment in which they are maintained brings about maximum utilisation of the natural recourses. There is a close correlation between an animal’s physiological response (such as body temperatures, respiration rates and pulse rates) and productivity.

Temperature is most important in determining which type of animal can be maintained in a particular region (Finch, 1986). The effects of heat on body temperature are determined not only by climate, but also by the available food and water. The further an animal moves away from its preferred body temperature, the more harmful temperature becomes to productive processes. Even small upward shifts in core temperature have profound effects on tissues and neuro-endocrine functions, which in turn reduce fertility, growth, lactation and ability to work (Finch, 1986).

Tropical degeneration is characterised not only by a marked reduction in fertility but also by stunted growth (Bonsma, 1983). Obviously, therefore, there is a close correlation between body temperature and productivity. This could result in a financial advantage in farming with well adapted animals as the loss in production during times of climatic extremes will be to a lesser extent when compared to breeds that are not adapted (Bonsma, 1983).

Farmers are constantly looking for ways to improve production and profitability of their livestock enterprises. Choosing a cattle breed to farm with is one of the most important decisions a farmer will have to make. However, this decision must be based on scientifically based results and not a perception, as this could cost the farmer greatly.

1.3 Problem identification

The availability of scientifically researched and publicised literature on the influence of breed, body condition score, coat score, respiration rate, tick burdens and hide thickness on the heat tolerance properties of different breeds in South Africa is limited. Especially pertaining to a breed such as the Drakensberger that is endemic to southern Africa.

The collecting and analysing of data to determine the susceptibility of six beef breeds to heat stress could have an advantage to the beef industry in South Africa. However, a necessity exists to determine whether simple assessments such as breed, coat score, coat colour, body condition score, respiration rate, and hide thickness can be used to predict whether an animal will respond auspiciously to heat stress.

The present work is an attempt to describe and evaluate breed, coat colour, coat type and body temperature (rectal temperature) in Afrikaner, Bonsmara, Braford, Charolais, Drakensberger and Simmentaler heifers in an attempt to resolve questions about these breeds adaptability to environmental heat.

1.4 Goal

The purpose of this study is to determine the effect of traits such as coat colour, coat score, hide thickness, body condition score, respiration rate, and breed on the perceived susceptibility of beef cattle to heat stress. Particular focus is to be put on the Drakenberger cattle breed, as no available scientific data is available on the susceptibility of these animals to heat stress.
The following specific goals are aspired.

i. to quantify the differences in rectal temperature, respiration rate, hide thickness, tick count, coat type and coat colour within a breed and between the different cattle breeds partaking in the study (Afrikaner, Braford, Bonsmara, Charolais, Drakensberger, Simmentaler);
ii. to determine whether there is a significant difference in rectal temperature, respiration rate, hide thickness, tick count, coat type, and coat colour within a breed;
iii. to determine whether there is a significant difference in rectal temperature, respiration rate, hide thickness, tick count, coat type, and coat colour between the six cattle breeds;
iv. to determine whether breed, coat colour or coat type or a combination of the three has a more significant effect on the rectal temperature and respiration rate of an animal;
v. to determine whether Drakensberger cattle succumb more easily to heat stress.

1.5 Hypotheses

i. coat type will have greater influence on an animals susceptibility to heat stress than coat colour;
ii. even though Drakensberger heifers are black, the Sanga ancestry of the breed will cause the Drakensberger to respond in like manner to the Afrikaner and Bonsmara to heat stress;

iii. the *Bos taurus* Charolais and Simmentaler breeds will be more prone to suffer from heat stress in a hot environment.

1.6 Facilities

On-the-farm research was conducted from July 2007 to the beginning of March 2008 on the farm, Quaggafontein, in the Zastron district in the south-eastern Free State. The required management equipment such as a holding pen and race were available at the study site.

In Chapter 2 previous researches and authors findings with regard to heat stress in cattle and factors influencing the climatic impact of heat on beef cattle will be reviewed.

CHAPTER 2

LITERATURE REVIEW

2.1 Heat stress

Heat stress in its advanced state referred to as heat stroke or sunstroke, which is an acute condition which occurs when the body produces or absorbs more heat than it can dissipate. It is usually caused by prolonged exposure to high temperatures. The heat regulating mechanisms of the body eventually become overwhelmed and unable to effectively deal with heat, causing the body temperature to climb uncontrollably (Wikipedia, 2009).

2.2 Physiological considerations

Heat stress in cattle can be determined as there is a change in metabolic rate of normal equilibrium in response to an increased change in ambient temperatures Stress, in its physical sense, cannot easily be measured in a biological system, but particular exhibitions of the stress, such as changes in body temperature, heart rate and respiration can be measured since the animal responds functionally to uphold homeostasis (Du Preez, 2000).

The cellular heat stress response is one of the acute systemic responses to heat stress. Gene networks within and across cells and tissues respond to environmental heat loads above the thermo neutral zone with both intra- and extracellular signals that coordinate cellular whole-animal metabolism (Collier *et. al.,* 2008). Activation of these systems appears to be initiated at skin surface temperatures exceeding 35°C as animals begin to store heat and rapidly increase evaporative heat loss mechanisms. Gene expression changes include 1) activation of heat shock transcription factor 1; 2) increased expression of heat shock proteins and decreased expression and synthesis of other proteins; 3) increased glucose and amino acid oxidation and reduced fatty acid metabolism; 4) endocrine system activation via extracellular secretion of heat shock proteins. If the stress persists, these gene expression changes lead to an altered physiological state referred to as “acclimation”, a process largely controlled by the endocrine system (Collier *et al.,* 2008).

Thermoregulation is the mechanism by which an animal maintains its body temperature and it entails a balance between heat gain and heat loss. Metabolic heat includes that necessary for maintenance plus increments for exercise, growth, lactation and gestation. High rates of these activities result in more heat gained from metabolism. In addition to heat gained from metabolism, heat is gained from the environment. During daylight hours most of the heat gained from the environment comes directly or indirectly from solar radiation. Heat is gained from convection and conduction only if the air temperature is higher than skin temperature (Ansell, 1974; Fuquay, 1981).

The dissipation of body heat is achieved by radiation, conduction and evaporation of moisture. Other minor methods of acquiring and dissipating heat are the voidance of faces and urine, raising ingesta to body temperature, and endothermic reactions. But these can be ignored in the context of animal management, with one exception: the ingestion of cold water, which could be of some significance (Ansell, 1974: Online).

Evaporation of moisture, whether from skin or lungs, is a major factor in heat dissipation, and it is unfortunate that cattle are less well endowed with sweat glands than heat tolerant mammals such as man (Ansell, 1974; Maree & Casey, 1993).

Evaporation is dependant on the humidity of the air and the wind velocity over the evaporating surface (Ansell, 1974; Fuquay, 1981; O’Neil, 2006). Although this is a controversial subject and involves complex physical concepts, it can be safely assumed that relative humidity readings as taken from a wet and dry bulb thermometer can be used as a guide to the evaporative capacity of the air (Ansell, 1974).

Conduction and radiation are simpler concepts of heat dissipation than evaporation (Ansell, 1974; Fuquay, 1981). They are dependant on environmental temperatures and on the surface area/body weight ratio of the animal, i.e. an animal with a large surface area in relation to its bulk (e.g. bat) can dissipate heat by these means more easily than one with a low surface area to body weight ration (Ansell, 1974; Maree and Casey, 1993; O'Neil, 2006).

An important aspect of heat dissipation is the diurnal variation in dry bulb temperature. Cattle can build up heat within their bodies to a considerable degree during the day without adverse effects if the night temperatures are sufficiently low for its dissipation (Ansell, 1974).

2.3 Factors influencing the climatic impact of heat on beef cattle

2.3.1 Coat colour

Any attention to heat tolerance of cattle in the tropics should include coat colour. This is because colour is a feature that mediates the impact of solar radiation and affects the extent of heat load on animals (Finch *et al.,* 1984). Finch *et al*. (1980) points out that white hair permits greater penetration of radiation into the fur than black hair. The radiation in the visible part of the spectrum (0.3 – 0.7 μm) is absorbed at or near the surface of black fur. Little is reflected, but a large quantity is re-radiated as long wave radiation (> 0.7μm) before it reaches the skin. More of the radiation in the visible spectrum is reflected from white fur, but is reflected in all directions and may penetrate deep into the fur, perhaps even to the skin before it is absorbed. The extent of this penetration and its consequence to inward flow of heat depends on the physical properties of the coat and environmental conditions (Finch *et al*., 1980).

Nevertheless, Finch *et al.* (1984) found that any heating effects from penetration of radiation into coats of light steers were outweighed by low absorption.

In a study by Schleger (1962) it was found that colour had a high heritability, approximated at 53%. Denise *et al*. (1988) estimated the heritability of coat colour to be 0.22 using a paternal half-sib analysis. A correlation between the incidence of medullation and the animal's ability to regulate rectal temperature was found by Dowling (1959) to be 0.95.

In studying why black goats were the most abundant domestic animal in the Negev and Sinai deserts Finch *et al*. (1980) found that the nett heat gain by radiation and convection was nearly twice as great for black goats as white goats when all were exposed to the hot desert sun. There was however no difference in either the rates of metabolic heat production or heat storage between black and white goats. All the additional heat gained by the black goats was lost evaporatively.

Rivera and Hansen (2001) found that coat colour affected rectal temperatures of cows ($P < 0.001$), with predominantly white Holstein cows having lower rectal temperatures than predominantly black Holstein cows. Research by Godfrey *et al.* (2003) contradicts research by Rivera and Hansen (2001) as coat colour in Holstein cows did not appear to have a strong influence on the response to elevated environmental temperatures as measured either by subcutaneous and vaginal temperatures. However, because coat colour of heifers had an effect on pregnancy and rectal temperatures, selecting for light coloured dairy cattle may be a way of mitigating effects of stress in dairy cattle in hot climates (Godfrey *et al.*, 2003). Denise *et al.* (1988) established that white coated Holstein cows (less than 40% black) required fewer services per conception and had fewer open days than mixed coat (40 - 60% black) and black coated Holstein cows.

Within a coat colour such as red there is a considerable range in intensity, e.g. from pale yellowish to a dark purplish shade in nominally red animals (Schleger (1962).

Schleger (1962) and Peters *et al*. (1982) show that within the range of red colours studied, there is no tendency for darker animals of the same coat type to have higher rectal or skin temperatures. It appears that the relationship between depth of colour and body temperature tends to be slightly negative, which suggests that the effect of solar heat load on darker animals is counterbalanced by some other characteristic favouring temperature regulation. Colour and gain are highly significantly correlated independent of coat type. The degree of red colour appears to be more important as an index of metabolic status rather than as a factor directly influencing heat tolerance. The relationships have been shown to apply in one major colour genotype and there is no reason to think that they apply between colour classes, i.e. in comparing blacks, reds, duns, etc. Peters *et al*. (1982) under sub tropical environmental conditions could not confirm the theoretically expected importance of coat colour for productive ability.

However, Finch *et al. (*1984) detected that when there was a striking difference in coat colour within a breed, the rate of environmental heat gain at the skin and the rate of evaporative water loss were greater for dark than light-coloured cattle and that in a breed that was easily stressed by heat, light-coloured animals had a major growth advantage. Finch and Western (1977) relate that in *Bos indicus* cattle, the inward flow of heat at the skin of black steers is 16% greater than for brown steers and 58% larger than for white ones. However, because these genotypes evaporate water efficiently, the variation in heat load due to colour has little effect on body temperature. Differences in heat load due to colour become important when water is limited as dark coated animals become more rapidly dehydrated. In environments with intense solar radiation, pigmentation of hair coat *per se* is likely to be much more essential for avoiding skin afflictions such as erythemas and skin cancer, than in reducing the intensity of solar radiation (Peters *et al*., 1982).

2.3.2 Coat type

Coat colour cannot be examined in isolation; similarly important is the type of coat and its interaction with colour. Structure affects penetration into, and the location of absorption of radiation within the coat (Finch *et al.,* 1984).

If air temperature exceeds skin temperature, or if an animal is in sunlight, there is an inward flow of heat through the coat to the skin. For this reason, resistance of the animal coat to environmental heat-flow is of great importance to the control of body temperature (Finch, 1986).

Turner and Schleger (1960) estimated the heritability of coat score to be 0.63 and the repeatability of coat score to be 0.60 or more over intervals of up to 17 months and report that coat scores are well correlated with body temperature and respiration rate.

Distinct seasonal differences ($P < 0.001$) in coat type in *Bos taurus* and *Bos indicus* type cattle have been reported by Schleger (1962) and Peters *et al*. (1982). Turner and Schleger (1960) also found highly significant differences in coat scoring between animals of the same breed and these differences persisted throughout different seasons.

Dowling (1959) recounts that the long, insulating type of winter coat is shed from the end of winter to the early summer, and the new fibres, which grow, are thicker and more medullated, though shorter. It would appear that the thicker, shorter, medullated fibres, which are stiffer, enhance air movement at the skin surface. Furthermore, the more medullated the fibre the more effective it would be in reflecting the infrared wavelengths of solar radiation.

Schleger (1962) found that the coats of Afrikaner cross cattle had a much greater proportion of new hairs in the coat than those of the British breeds, whereas the position was reversed in January. The emergence of new hairs during spring-summer-autumn is a biphasic process with peaks in September and January. This breed difference appears critical in the study of the coat type-coat colour relationship (Schleger, 1962).

A deep or woollier coat type is negatively correlated to tolerance of sun, time engaged in grazing and weight gain, and is exacerbated by a dark coloured coat (Finch *et al.,* 1984). This equates with former evidence that variation in coat type is a factor which adds to differences between and within breeds in heat tolerance and performance (Turner & Schleger, 1960).

Turner and Schleger (1960) conclude that a sleek coat is meaningful in favouring heat dissipation, but may have even greater significance as a directive of metabolic efficiency or of a capacity to react favourably to stress. Bonsma (1983) repeatedly emphasises the importance of coat type in adaptation and presents extraordinary examples of it. Bonsma (1983) observed that the coats of Afrikaner cattle were smooth during the summer months and produced more sebum, which acts as a tick-repellent. The short hair and greasy coats develop much less static electricity when stroked, do not matt and afford little protection for the ticks which do not like to be exposed to solar radiation. As a result fewer ticks are found on smooth coated animals.

Evidence was found by Olson *et al.* (2003) that support the existence of a major gene (designated as the slick hair gene), dominant in mode of inheritance that is responsible for producing a very short, sleek hair coat. Cattle with slick hair were observed to maintain lower rectal temperatures (Olson *et al.,* 2003). This gene was found in Senepol cattle and criollo (Spanish origin) breeds in Central and South America. The decreased rectal temperatures observed for slick haired crossbred calves compared to normal haired contemporaries ranged from 0.18 to 0.4°C. An even larger decrease in rectal temperatures (0.61°C; $P < 0.01$) was observed in lactating Carora x Holstein F_1 crossbred cows, even though it did not appear that these cows were under severe heat stress (Olson *et al.,* 2003). There were indications that the slick-haired calves grew faster immediately following weaning and that their growth during the cooler months of the year was not compromised significantly by their reduced quantity of hair. In the Carora x Holstein crossbred cows there was a positive effect of slick hair on milk yield under dry, tropical conditions (Olson *et al.,* 2003).

While researching whether slick-haired Holstein cows regulate body temperature more effectively than wild-type Holstein cows when exposed to acute heat stress in an indoor and outdoor environment Dikmen *et al.* (2008) found that in both environments slick haired cows had lower vaginal temperatures (indoor: 39.0 vs. outdoor 39.4°C) and respiration rate (indoor 37 vs. 79 breaths/min: outdoor 97 vs. 107 breaths/min) than wild-type cows indicating that slick haired Holstein cows can regulate body temperature more effectively than wild-type cows during.

Peters *et al*. (1982) argue that coat characteristics seem to be of limited value in selection of beef cattle to improve adaptation as an unfavourable coat type did not have a negative effect on growth rate and that coat type was not so much the cause of weight performance but rather its result. The selection criteria to improve performance, however, will not be coat type *per se* but rather the animal's productive adaptability expressed as weight gain per reproductive unit. However, coat type can play a role in avoiding ecto parasitic infestations.

2.3.3 Breed

During the separate evolution from *Bos taurus* (e.g. Angus, Charolais and Simmentaler), zebu cattle (*Bos indicus,* e.g. Afrikaner, Brahman and Nellore) have acquired genes that confer thermo tolerance at the physiological and cellular levels. Cattle from zebu breeds are better able to regulate body temperature in response to heat stress than are cattle from a variety of *B. taurus* breeds of European origin (Hansen, 2004). Moreover, exposure to elevated temperature has less deleterious effects on cells from zebu cattle than other European breeds. Superior ability for regulation of body temperature during heat stress is the result of lower metabolic rates as well as increases capacity for heat loss. As compared to European breeds, tissue resistance to heat flow from the body core to skin is lower for zebu cattle while sweat glands are larger (Hansen, 2004). Properties of the hair coat in zebu cattle enhance conductive and convective heat loss and reduce absorption of solar radiation. At cellular level, genetic adaptations to resist deleterious effects of elevated temperature result in preimplantation embryos from zebu being less likely to be inhibited in development in hot climates but success has been limited by other unfavourable genetic characteristics of these cattle (Hansen, 2004).

Whilst investigating the physiological responses of *Bos Taurus* and *Bos indicus* cattle to prolonged, continuous heat and humidity the results of Beatty *et al.* (2006) suggest that *Bos Taurus* cattle experience significant physiological changes during exposure to prolonged and continuous high heat and humidity, with alterations persisting some days after the heat stress conditions subside. *Bos indicus* experience similar but less pronounced physiological changes (Beatty *et al.*, 2006)

Results of research done by Hernàndez-Cerón *et al*. (1987) demonstrate that embryos from Brahman and Romosinuano breeds, a *Bos Taurus*, Criollo-derived breed, are more resistant to elevated temperature than embryos from Angus. Thus, the process of adaptation of Brahman and Romosinuano breeds to hot environments resulted in both cases in selection of genes controlling thermo tolerance at cellular level.

2.3.4 Sweating and evaporative heat loss

Sweating and panting differ from other processes of heat-loss in that they are controlled thermoregulatory mechanisms (Finch, 1986).

As ambient temperatures rise, evaporative heat loss becomes a principal avenue of heat loss because it is not dependant on the thermal gradient, as are conduction and convection. At high ambient temperatures during the day, most heat loss occurs through evaporative cooling (Ferguson and Dowling, 1956; Fuquay, 1981; West 1986; Blackshaw and Blackshaw, 1994).

Schleger and Bean (1971) report that the two skin characters most closely related to sweating performance are density of dermal arteries and the percentage of active follicles and these characters are closely associated. It appears that the growth phase of the hair follicle has a critical effect on the capillary supply to the sweat gland. A poor relationship between sweat gland size and sweating rate indicates that other factors have an important effect on sweat gland performance. The state of activity of the hair follicles appears to be of prime importance. The effect of the hair growth phase on the capillary supply to the sweat gland is far more critical than its effect on sweat gland size. Finch (1986) adds that the ability of an animal to increase blood flow to the sweat gland influences sweat production. Contradicting Schleger and Bean (1971), studies by Hayman and Nay (1958), show that a large sweat gland volume is associated with a higher sweating competence and enables an animal to maintain a lower body temperature. Ferguson and Dowling (1956) suggest that the source of individual variation in heat tolerance may well arise partly from corresponding variation in the number and activity of the apocrine glands and animals ability to increase blood flow to the sweat gland.

Seasonal differences in sweating competence occur as there are three times as many active follicles in the shoulder region and twice as many in the flank region in summer compared to the winter (Schleger and Bean, 1971). Hayman and Nay (1958) have observed similar seasonal changes in sweat gland activity.

Sweating performance varies considerably within the same body region and this difference is as great as or greater than reported between body regions and between different seasons. The sweating pattern is more evident in British breeds than in Brahman crossbreeds (Schleger and Bean, 1971). Schleger and Turner (1965) found that Zebu crossbreds had lower sweating rates than British cattle under mild conditions, but higher rates at higher levels of stress. It was clear that Zebu types were more responsive in sweating and thus spared strain on other aspects of thermoregulation.

Under hot conditions animals with heavier coats have a higher body temperature and sweat more due to a greater stimulus to sweat. Under mild conditions sleek-coated animals favour convective heat loss, but under hot conditions sweat more because their sleek coat is a reflection of an active physiological state of the skin (Schleger and Turner, 1965). Dikmen *et al.* (2008) found that slick-haired Holstein cows were better able to regulate body temperature than wild-type Holstein cows due to an in increased sweating rate.

Finch (1986) found that in *Bos taurus,* sweating rate was significantly negatively related to the upsurge in absolute humidity. There was no negative effect of absolute humidity on the sweating rate of *Bos indicus*, which increased despite the increase in humidity. He concluded the breed differences were due to differences in the coats; that of *Bos taurus* entrapping water vapour in the air spaces between the hairs and thereby hindering evaporation.

Sweating rates decline in the face of constant or rising dry bulb temperatures, the decline occurring sooner in British than Zebu cross calves and appears to correspond to the phenomenon of sweat gland fatigue or hidromeiosis in humans. The onset of hidromeiosis is delayed in subjects that are well-adapted (Schleger and Turner, 1965).

Zebu cattle are also susceptible to heat stress when drinking water is a limiting factor as dehydration results in a delay in sweating in this genotype as strict thermoregulation gives way to water conservation (Finch *et al.,* 1984).

Breeds adapted to periods of intermittent watering reduce evaporative water losses. Changes in the body thermo sensitivity cause a delay in the onset of sweating and panting until critical body temperatures are reached. The animal stores heat rather than reducing water reserves for evaporative cooling. In *Bos indicus* this allows significant heat storage during the day, while maintaining a higher, but still physiologically acceptable upper range. The stored heat is then dissipated non-evaporatively at night (Finch, 1986).

Following exposure to heat, cattle appear to acclimatise within 2-7 weeks (Blackshaw and Blackshaw, 1994). It must be kept in mind that in the process of acclimatisation, temperate species lower their metabolic rate and increase thermoregulatory ability, but efficiency of heat-loss is never as great as in indigenous species (Finch, 1986).

2.3.5 Respiration

As mentioned earlier, the inevitable energy transformations that occur within animal tissues produce heat. Some of this heat, about 15% in cattle under high heat loads, is lost directly from the body core via the respiratory tract (Finch, 1986).

Because the primary non evaporative means of cooling for the cow (radiation, conduction, convection) become less effective, the cow becomes increasingly reliant upon evaporative cooling of sweating and panting (West, 2003).

Panting is a controlled increase in respiratory frequency accompanied by a decrease in tidal volume, the purpose is to increase ventilation of the upper respiratory tract, preserve alveolar ventilation, and thereby elevate evaporative heat loss. Most heat exchange takes place at the nasal epithelial lining, and venous drainage can be directed to a special network of arteries at the base of the brain whereby countecurrent heat transfer can occur, which results in selective brain cooling (Robertshaw, 2006).

In both sheep and cattle a high respiratory rate is always associated with severe heat stress, non-adaptation and a ‘last-ditch’ attempt to control body temperature (Finch, 1986). Bennett *et al.* (1985) found that the cooling effect on Shorthorn steers of sheltering in high shade was a reduction of 1.03 respirations per minute ($P > 0.001$).

Whilst investigating the physiological responses of *Bos Taurus* and *Bos indicus* cattle to prolonged, continuous heat and humidity Beatty *et al.* (2006) found that respiratory rate increased ($P < 0.001$) by day 11 compared with values of lower ambient temperature on the first and second day. The increase in respiratory rate coincided with a decrease in the partial pressures of carbon dioxide and bicarbonate in venous blood. However, during the hottest period, average daily venous blood pH remained unchanged (Beatty *et al.*, (2006).

2.3.6 Body condition

Beef cattle breeds can be grouped according to production traits into late maturing, early maturing and indigenous breeds. The late maturing types include exotic or continental breeds such as the Charolais, and British beef breeds. Two factors stimulated the demand for these cattle types namely the demand for fast- growing animals and lean meat, thus resulting in the late depositing of fat (Maree & Casey, 1993).

Reproduction is the most important factor in determining profitability in a cow calf enterprise. Poor reproductive performance is directly linked to the percentage of body fat in beef cows. Body condition scoring (BCS) is an easy and economical way to evaluate the body fat percentage of a cow. Beef cattle have nutrient requirements in priority order for body maintenance, foetal development, lactation, growth and breeding. Beef cattle store excess nutrients as body fat (Rossi and Wilson, 2008).

Epperson and Zalesky (1995); Martin and Noecker (2006) report that hot and humid weather creates dangerous conditions for all livestock, particularly heavy fed cattle. Dark-coloured beef cattle on a high-energy diet, carrying lots of body condition, will be first affected by heat and humidity.

Lean body condition increases the ability to lose heat. “Fat” cattle have greater risk of heat stress because excess body fat acts as insulation and slows body heat loss (Coventry and Phillips, 2000)

2.3.7 Hide thickness and ticks

Cattle primarily cool themselves by increasing the blood flow to the surface of their bodies. This is called vascularisation. Cooling through the skin is far more important than panting in cooling the animal. Animals with thick hides, which allow for more blood flow are far more heat tolerant than animals with thin hides. Thick loose hides also help and animal to repel flies and ticks (Nation, 2009).

Spickett *et al.* (1989) found that indigenous Nguni cattle harboured significantly fewer ticks such as *Amblyomma hebraeum*, *Boophilus decoloratus,* and *Hyalomma* spp. during periods of peak abundance than either Bonsmara or Hereford cattle. However, individual tick indices could not be correlated with hair length, skin thickness, or conglutinin titres. The consistently large percentage of Nguni cattle showing high tick resistance indicates a superior level of natural immunity in the breed. The relative incidence of individuals in high resistance classes reflected an increase in resistance with exposure to ticks and the potential for selection for tick resistance within all three breeds.

Literature examining the relationship between body temperature and tick infestations is scarce. However, O’Kelly and Spiers reported significant positive correlations between body temperature of the host and number of ticks maturing. Turner and Schleger (1960) report that body temperature may be an indirect measure of the suitability of the skin and coat for protecting ticks, since coat scores are well correlated to body temperature. Bonsma (1983) stated that ticks preferred to infest cattle on the areas of the body where the skin was significantly thinner and where they were protected from direct solar radiation.

2.4 Heat stress in cattle and its effects on production

It is well documented that the stress of hot environments lowers productive reproductive efficiency in farm animals (Ansell, 1974; Fuquay, 1981; Turner, 1982; Blackshaw and Blackshaw, 1994; Du Preez, 2000). Through studies in controlled-environmental chambers, upper critical temperatures have been established for a number of production traits; these temperatures fall between 24 and 27°C for most traits and most species (Fuquay, 1981).

2.4.1 Reproduction

Most research on the effects of heat stress on reproduction has focused on its relationship to conception rate, which would include both fertilization and early embryonic mortality.

Research done by Turner (1982) at the National Cattle Breeding Station, Rockhampton, Australia found that the reduction in the calving rate due to 0.1°C increment in rectal temperature was 0.009 at 39°C, 0.02 at 40°C and 0.035 at 41°C. Even in relatively heat-tolerant Zebu crossbreds and in a relatively mild environment, both the mean rectal temperature and its genetic variability within a herd had quite large effects on reproduction. The heritability of rectal temperature was 0.25 (s.e. 0.12) and its genetic correlation with fertility was – 0.76 (s.e. 0.35) (Turner, 1982).

Turner (1982) reports that the response of fertility to a given change in rectal temperature was the same for *Bos taurus* as well as *B. indicus x B. taurus* half-bred lines. The average depression of fertility due to heat susceptibility was 0.15 to 0.25 in British-breed and approximately 0.10 in Zebu-cross herds.

A lower conception rate has been reported (Fuquay, 1981; Gwazdauskas, 1985) for cows with above normal body temperatures at time of insemination than for cows with normal temperatures. The most critical time appears to be the period from insemination to a few days afterward. Rivera and Hansen (2001) found that a pattern of temperatures similar to those experienced by hat stressed cows for 192 h (day 0-8 after insemination) reduced development of embryos to the blatocyst stage ($P < 0.05$)

Fuquay (1981) found that heat stress reduced the duration and intensity of expression of estrous. In a study of reproductive records of the dairy herd at the Mississippi State University more short estrous cycles (< 15 days) and long estrous cycles (>30 days) were noted during the summer. However, the reduction in intensity of estrous ("quiet" estrous) resulting in missed estrous appeared to be the more serious problem (Ansell, 1974; Fuquay, 1981; Gwazdauskas, 1985).

Gwazdauskas (1985) established that heat stress caused estrogens to be lower during late gestation and displayed its physiological action through lower calf birth weights. Ansell (1974) reported that heat stress caused gestation periods to be shorter by approximately 10 to 14 days and that birth weight of calves were significantly reduced.

Impaired spermatogenesis and lower testosterone during early exposure to hyperthermia have been reported by Gwazdauskas (1985). Zhu and Setchell (2004) support previous work demonstrating that both sperm in the epididymis and germ cells in the testis of mice are susceptible to damage by environmental heat stress, with spermatocytes being most vulnerable. However, it was found by Brito *et al.* (2002) that semen quality in *Bos indicus* and *Bos taurus* AI bulls in Brazil was not significantly affected by ambient temperature and humidity in a temperate environment.

2.4.2 Milk production

Davison *et al*. (1988); West (2003) found that increasing air temperature, temperature-humidity-index and rising rectal temperature above critical thresholds are related to decreased dry matter intake (DMI) and milk yield and to reduced efficiency of milk yield.

Finch (1986) noticed that animals on a high plain of nutrition reacted more dramatically to hot conditions than those on a low plain. The declining feed intake was a major cause of a reduction in milk yield while a reduction in the conversion of feed energy units to production energy units during heat stress has been reported in beef heifers and lactating dairy cows.

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the study site

All experimental procedures were conducted on the farm "Quaggafontein" located (30 ° 46' S, 27° 22' E), situated in a Grassland region, south of Zastron, in the south-eastern Free State, South Africa. The farm is 1 488 meters above sea level. Approximately 2000 ha are fenced for use on the farm. The research was conducted from the winter of 2007 (July) to the summer of 2008 (March) to evaluate the effect of heat stress on six beef breeds.

The most widely used of the classifications of rangeland types of southern Africa is that of Acocks (Maree & Casey, 1993). The veld type in Zastron is described by Acocks as transitional *Cymbopogon*, *Themeda* veld (Acocks, 1975). Reports by Maree & Casey (1993) summarise the seasonal value of the forage produced as mixedveld. Mixedveld is intermediate between the two extremes of sweetveld and sourveld. Sweetveld has the capacity to support animals year-round; this implies that plant material produced during the summer growing season, remains sufficiently palatable and nutritious during the subsequent winter to support a reasonable level of animal performance. Sourveld, in comparison, loses its palatability and nutritive value when it matures and becomes fibrous, so forage produced will support animal performance only during the active growing season.

The study site is situated in a temperate eastern plateau climatic zone having cool wet summers and cold dry winters (Maree & Casey, 1993). Rainfall varies between and mm p.a. Mean monthly minimum and maximum temperatures (°C) for Aliwal North, which falls under the same climatic zone and is the closest weather station monitored by the SA Weather Service, is given in Table 1.

Table 1: Mean monthly minimum and maximum temperatures (°C) for Aliwal North

	Average daily minimum temperature (°C)	Average daily maximum temperature (°C)	Average rainfall (mm)
July 2007	- 3.8	17.9	3.8
August 2007	-1.0	21.4	12.6
September 2007	4.5	23.7	7.4
October 2007	9.0	26.4	57
November 2007	9.0	27.1	59.2
December 2007	13.0	32.6	114
January 2008	13.7	30.5	78.8
February 2008	14.2	30.8	76.8
March 2008	10.8	26.6	41.4

Source: SA Weather Service (2009).

3.2 Identification of animals

All the heifers that participated in the study were born in the same area and climatic zone where the study was to be done. This was done to minimise the effect of adaptation. However, Blackshaw and Blackshaw (1994) found that acclimatisation begins within two weeks and is complete in 4-7 weeks. Only animals from stud breeders were selected as to adhere to breed standards of each breed.

Ten heifers each of the Afrikaner, Bonsmara, Braford, Charolais, Drakensberger and Simmentaler breeds, all between 7 and 9 months of age, were introduced onto the farm at the beginning of July 2007, during mid winter. All the heifers were weaned prior to the adaptation period. The experimental animals were kept separate from the main herd of Drakensberger animals also run on the farm.

The Bonsmara and Simmentaler heifers had to be withdrawn from the research at the beginning of February 2008 as these animals were to be bred at an age of 18 months and as a consequence had to be returned to their owners.

3.3 Plane of nutrition

Animals were kept extensively on the natural pasture prevailing in the region. In summer a mineral lick containing 57 g/kg crude protein, 120 g/kg calcium and 45 g/kg phosphate was supplemented on an *ad libitum* basis. In winter a protein-mineral lick containing 466 g/kg crude protein, 37 g/kg calcium, 19 g/kg phosphate and 4.4 MJ/kg ME was provided on an *ad libitum* basis (mean intake of 250g/animal/day was achieved).

3.4 Processing and disease prevention

On arrival all heifers were tagged, weighed and given a vitamin A injection. Vaccination of heifers commenced subsequent to the winter section of the trial to prevent any vaccine induced fevers during the trial. In September animals were vaccinated against black quarter, lumpy skin disease and Anaplasmosis. Due to excessively heavy tick burdens in October and November animals were treated with a pour on dip to contain tick infestations. Animals were treated against liver fluke prior to the commencement of the summer section of the trial.

3.5 Data collected during the study

3.5.1 Breed

The herd comprised of four purebred and two synthetic lines as summarised in Table 2.

Table 2: Grouping of breeds according to their genetic composition.

	Type	
Afrikaner	Zebu (*Bos indicus)*	Pure bred
Bonsmara	*Bos indicus x Bos taurus* (⅝ Afrikaner, ⅜ Herford/ Shorthorn)	Synthetic line
Braford	*Bos indicus* x *Bos taurus* (⅝ Brahman x ⅜ Hereford)	Synthetic line
Charolais	*Bos taurus*	Purebred
Drakensberger	*Sanga*	Purebred
Simmentaler	*Bos taurus*	Purebred

3.5.2 Body weight and body weight gain

All the heifers were weighed with a Rudd © electronic scale on the 3rd of August 2007, 8th of January 2008 and again on the 5th of March 2008 as to determine the influence of heat stress on production expressed as weight gain or loss over the experimental period.

3.5.3 Coat score

The coat scoring system described in Table 3 and applied in the study was found to be consistent and meaningful by Turner and Schleger (1960) as well as Peters *et al.* (1982). Length of hair or the depth of the coat was the principal criterion of classification, with "handle" a modifying factor. The coat on the midside was primarily examined, secondary attention being given to other areas, particularly in the case of severely long coats or when animals were in the process of shedding.

The following is a general description of the scoring system used.

Table 3: Coat scoring system

Coat Score	Coat Type	Description
1	Extremely short	Hairs extremely short and closely applied to the skin. Found in Zebu's, in some of their crossbreeds, and very rarely in mature Hereford or Shorthorn cows in summer;
2	Very short	Coat sleek, hairs short and coarse, lying flat, just able to be lifted by thumb;
3	Fairly short	General appearance smooth-coated. Hairs easily lifted, usually fairly coarse;
4	Fairly long	Coat not completely smooth, somewhat rough, patches of hairs being curved outwards, or whole coat showing sufficient length to be easily ruffled;
5	Long	Hairs distinctly long and lying loosely; predominantly coarse Hairs erect, giving fur-like appearance;
6	Woolly	Fingers are partly buried in the coat. Fine hairs of under-coat give soft handle;
7	Very woolly	The more extreme expression of 6, with greater length and "body", and heavy cover extending to neck and rump.

Source: Turner and Schleger (1960)

Coat score was determined in August 2007 (winter), at the beginning of December 2007 (summer) and again in January and February 2008. Additional observations of the coat scores of the Afrikaner, Braford, Charolais and Drakensberger heifers were done in February and March of 2008.

3.5.4 Coat colour

Coat colour was determined visually and divided into eight different colour groups as shown in Table 4 (Peters *et al*., 1982)

Table 4: Classification of coat colour

Score	Colour
2	Grey
4	Yellow-fawn
6	Light-red
8	Red
10	Dark-red
12	Brown
14	Dark-brown
16	Black

Source: (Peters *et al*., 1982).

Coat colour was determined subjectively in August 2007 (winter). Due to shedding of the winter coat in spring a second appraisal of the coat colour was done in December 2007 (summer).

3.5.5 Body condition score

A description of each body condition score is listed in Table 5. Body condition scores were determined in early January 2008 on all sixty animals. However in early February and March 2008 body condition scoring was only done on the Afrikaner, Braford, Charolais and Drakensberger heifers.

Table 5: Description of body condition scores (BCS) (1 being thin and 9 being obese).

BCS	Detailed Description
	Thin
1	Clearly defined bone structure of shoulder, ribs, back, hooks and pins easily visible. Little muscle tissue or fat present.
2	Small amount of muscling in the hindquarters. Fat is present, but not abundant. Space between spinous process easily seen.
3	Fat begins to cover loin, back and fore ribs. Upper skeletal structures visible. Spinous process easily defined.
	Borderline
4	Fore ribs becoming less noticeable. The transverse spinous process can be identified by palpitation. Fat and muscle tissue not abundant, but increasing in fullness.
	Optimum
5	Ribs are visible only when the animal has been shrunk, processes not visible. Each side of the tail head is filled but not mounded.
6	Ribs not noticeable to the eye. Muscling in hindquarters plump and full. Fat around tail head and covering the fore ribs.
7	Spinous process can only be felt with firm pressure. Fat cover in abundance on either side of tail head.
	Fat
8	Animal smooth and blocky appearance; bone structure difficult to identify. Fat cover abundant.
9	Structures difficult to identify. Fat cover is excessive and mobility may be impaired.

Source: Rossi & Wilson (2008)

3.5.6 Hide thickness

The hide thickness was determined using a calliper which slips at a constant pressure. The skin over the midside area was measured as Tulloh (1961) found that the skin over this area is relatively uniform in thickness. Hide thickness was measured in December 2007 and again in January 2008. An additional hide thickness measurement was taken in March 2008 on the Afrikaner, Braford, Charolais and Drakensberger heifers.

3.5.7 Heat stress and body (rectal) temperature

Heat stress in cattle can be analysed using the empirical temperature-humidity-index (THI) which relates stress to both daily maximum temperature and dewpoint temperature. This relationship has been shown to be a robust predictor of heat stress. The THI has minimal input requirements and has been used in a variety of environments which makes it suitable for a broad scale assessment of issues such as heat stress (Howden and Turnpenny, 1997).

Using THI and the guidelines of the Livestock Conservation Institute, the spatial and temporal distribution of heat stress areas (HSRA) have been mapped for each month of the year. In South Africa, progressive expansion of HSRA commences from the north-west in August, peaks at 100% of the area of South Africa in January and progressively contracts from February, reaching zero in July (Maree & Casey, 1993).

A Kestrel® 4000 Pocket Weather Tracker was used to measure dry-bulb temperature and wet-bulb temperature at 14:00 on days when relevant data was to be recorded. The Kestrel® 4000 Pocket Weather Tracker had the following specifications:

Dry-bulb temperature:

Response time:	1 second
Units:	°F, °C
Accuracy:	± 1.0 °C

Wet-bulb temperature:

Response time:	1 minute
Units:	°F, °C
Resolution:	0.1
Accuracy:	± 2.0 °C

The relevant weather data was recorded on days when data collecting was done and used to calculate the Temperature Humidity Index (THI).

The following calculation was used to determine THI index values for cattle (Howden & Turnpenny, 1997; Du Preez, 2000):

THI = tdb + 0,36 tdp + 41,2

where tdb = dry-bulb temperature in °C (maximum temperature at 14:00)
tdp = dew-point temperature at 14:00

Condensation first occurs when an air-water vapour mixture is cooled at a constant pressure. The dew-point temperature is the temperature at which condensation occurs and was calculated as follows:

tdp = dry-bulb temperature at 14:00 minus wet-bulb-temperature at 14:00.

The Livestock Weather Safety Index (LWSI) of the Livestock Conservation Institute (1970) as set out in Table 6 was used as a basis for classifying various categories of the THI values.

Table 6: Livestock Weather Safety Index (LWSI) categories according to the temperature-humidity index (THI) values

THI Value	LWSI
70 or less	Normal
71 – 78	Alert
79 – 83	Danger
83 or above	Emergency

Source: Du Preez, (2000)

Differences in body temperature (rectal temperature) of the same ten heifers of each breed which did not experience heat stress during August 2007 (Temperature Humidity Index [THI] < 70, 10-day period) and which did experience heat stress during December 2007 and January 2008 (THI > 70, 10-day period) were measured using a digital rectal thermometer. An additional seven observations of rectal temperatures were taken during February 2008 on the Afrikaner, Braford, Charolais and Drakensberger heifers, the same ten heifers of each breed being used as formerly. On days when data was to be recorded, animals were rounded up and placed in a holding pen at 13:00. The measuring of rectal temperatures commenced at 14:00.

3.5.8 Respiration rate

Respiratory rate was counted visually from flank movements in a given time as recorded with a chronometer, and were standardised to one minute. Care was taken to ensure that animals were standing freely in the crush and were placid while measurements were taken. Respiration rate was measured on five individual occasions in December 2007 and again on six separate occasions in February 2008 on the Afrikaner, Braford, Charolais and Drakensberger heifers. The respiration rate was determined concurrently with the rectal temperatures.

3.5.9 Tick burden

Animals in the experimental group were allowed to become naturally infested with ticks without acaricidal intervention except for patch treatments applied in October and November to contain *Boophilus decoloratus*, *Hyalomma marginatum rufipes* and *Rhipicephalus evertsi* infestations. Two officers, one on either side, carefully examined the restrained animals, recording all visible ticks. The species of ticks were not specified and ticks were not removed from the animal. Tick burdens were determined on five occasions during February 2008 on the Afrikaner, Braford, Charolais and Drakensberger.

3.6 Statistical Analysis

The study was executed during late winter and early summer months (December 2007- February 2008) using the repeated experimental design. The parameters of 6 beef breeds (Afrikaner, Charolais, Nguni, Drakensberger, Bonsmara and Simmentaler) measured included tick count, respiration rate, hide thickness, coat colour, coat score, body condition score, respiration rate and rectal temperature to test for significant difference between breed taking into account the possible changes over time.

The SAS procedure for general linear models (PROC GLM) using the repeated measures option was used to test for significant differences between groups (breeds) over time (SAS, 2004).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Body weight gain

The mean weight gains are presented in Table 7 and 8. In Table7 the weight gains from 3 August 2007 to 8 January 2008 of all six breeds are presented. In Table 8 the mean weight gains of the Afrikaner, Braford, Charolais and Drakensberger heifers from 3 August to 5 March 2008 are presented.

Table 7: Mean weight gain in kilograms (kg) (3 August 2007 – 8 January 2008) and s.e per breed

Parameter	**Afrikaner (*n*=10)**	**Bonsmara (*n*=10)**	**Braford (*n*=10)**	**Charolais (*n*=10)**	**Drakensberger (*n*=10)**	**Simmentaler (*n*=10)**
Weight gain (kg)	80.5 ± 3.45^{a}	104.5 ± 4.74^{b}	97.0 ± 3.59^{b}	102.0 ± 4.90^{b}	98.5 ± 1.67^{b}	120.0 ± 2.79^{c}

[1]Means in the same row with different superscript letters differed significantly: $P < 0.0001$

In the first section of the research where all breeds partook in the study, the Afrikaner gained significantly ($P < 0.001$) less weight than the Bonsmara, Braford, Charolais, Drakensberger and Simmentaler heifers. The Simmentaler heifers had the greatest weight gain of 120.0 (s.e. 2.79) kg. No significant differences in weight gains were observed between the Bonsmara, Braford and Drakensberger heifers. On the basis of mean weight gain, the breeds have been ranked in order of decreasing weight gain as Simmentaler > Bonsmara, Braford, Charolais, Drakensberger > Afrikaner.

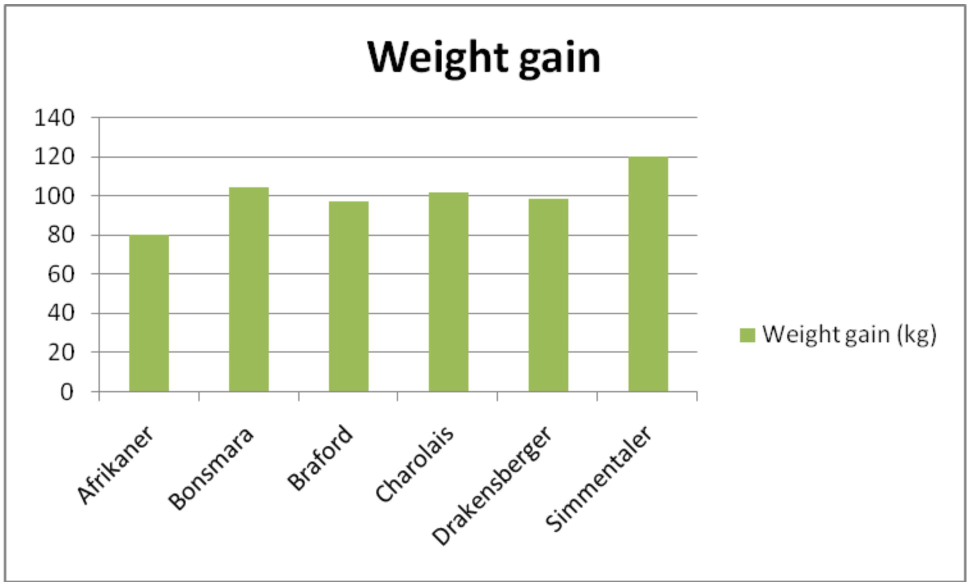

Figure 1: Mean weight gain in kilograms from 3 August 2007 to 8 January 2008

During the second section of the study in which the Bonsmara and Simmentaler breeds were not present, the Afrikaner had the least overall weight gain of 119.0 ± 2.45kg and the significance being $P < 0.0001$. No significant difference in weight gain was reported between the Braford, Charolais and Drakensberger heifers.

Table 8: Mean weight gain (3 August 2007 – 5 March 2008) and mean s.e. per breed

Parameter	**Afrikaner (*n*=10)**	**Braford (*n*=10)**	**Charolais (*n*=10)**	**Drakensberger (*n*=10)**
Weight gain (kg)	119.0 ± 2.45[a]	136.5 ± 3.17[b]	145.0 ± 6.32[b]	140.0 ± 2.93[b]

[1]Means in the same row with different superscript letters differed significantly: $P < 0.001$

While doing research on heat stress risk factors of feedlot heifers Brown-Brandl *et al.* (2006) found that Charolais cattle gained significantly more than all the other breeds of cattle tested. In the present study the Charolais did not gain significantly more weight than the Bonsmara, Braford or the Drakensberger heifers. However, it must be kept in mind that in the present study cattle grazed on native pastures. Niemelä *et al.* (2008) found that the interaction between breed and pasture type tended to be significant and that in Finland the Simmentaler was capable of slightly better utilisation of coastal meadows than the Limousine. In the present study the Simmentaler also gained significantly more weight than the other breeds.

Prayaga and Henshall (2005) report that genetic correlations between growth traits and heat tolerance traits such as rectal temperature and coat scores were moderately negative implying that as the ability of an animal to handle heat stress increases, growth also increases at the genetic level. A significant negative correlation between rectal temperature and live weight gains were observed in British purebreds (Prayaga, 2003).

Cattle breeds in the beef industry can be grouped according to specific production traits. The main difference between breeds can be explained in terms of differences in adaptability and differences in maturity types. Maree and Casey (1993) observed that it would be incorrect to compare breeds on growth rate as a breed with high growth rate is not necessarily better than one with a lower growth rate since growth rate alone does not relate to feed efficiency or to comparable maturity type. The real challenge under range conditions is to measure production per unit of biomass on the land and here all results indicate that cattle or breeds of moderate or even small-frame size thrive.

4.2 Coat colour and breed

There was not sufficient variation in coat colour within breeds and between certain breeds to assess the relationship of coat colour to heat tolerance (rectal temperatures) as coat colour was a function of breed.

4.3 Coat Score

The Bonsmara and Simmentaler heifers had to be withdrawn from the research at the beginning of February 2008 as these animals were to be bred at an age of 18 months and as a consequence had to be returned to their owners resulting in only three measurements taken for CS for these two breeds.

As seen in Table 9, distinct seasonal differences in coat score in all breeds were measured as well as significant differences in coat score between breeds.

Table 9: Least-squares means (± s.e.) for coat score (CS) per breed with a value of 1 being extremely short and 7 very woolly

Para-meter	Month	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
CS 1	August	3.6 ± 0.16^{a}	4.3 ± 0.15^{b}	4.8 ± 0.13^{b}	6.4 ± 0.16^{c}	4.7 ± 0.15^{b}	6.2 ± 0.13^{c}
CS 2	December	3.2 ± 0.20^{ab}	2.8 ± 0.20^{a}	3.0 ± 0.26^{a}	4.0 ± 0.21^{b}	3.5 ± 0.27^{ab}	3.5 ± 0.22^{ab}
CS 3	January	1.7 ± 0.15^{a}	1.9 ± 0.18^{a}	2.7 ± 0.21^{bc}	3.6 ± 0.16^{d}	2.2 ± 0.13^{ab}	3.1 ± 0.10^{cd}
CS 4	February	1.3 ± 0.15^{a}	-	2.5 ± 0.17^{b}	3.4 ± 0.16^{c}	1.7 ± 0.15^{a}	-
CS 5	March	1.1 ± 0.10^{a}	-	2.5 ± 0.17^{b}	4.0 ± 0.26^{c}	1.8 ± 0.13^{d}	-

[1]Means in the same row with different superscripts differ significantly: P < 0.0001, except on the second day of sampling (CS2) where the significant difference is P < 0.01.

Highly significant (P < 0.0001) differences in coat scores were observed in each of the five days of observation between breeds except on the second day where the significant difference between breeds concerning coat score was slightly lower (P<0.01). The Afrikaner had the lowest coat score on the 1st, 3rd, 4th and 5th observation days and the Charolais the highest coat score throughout the course of the study. During the first section of the study where all six breeds participated, no significant differences in coat scores were observed between the Bonsmara and Drakensberger, the Drakensberger and Braford as well as between the Charolais and Simmentaler heifers. On the second, third and fourth observation days no significant differences in coat scores were observed between the Afrikaner and Drakensberger heifers.

From the results of the study it is clear that there were highly significant differences in coat scores between breeds and that the coat scores were affected by season as mean breed coat scores decreased from August through to February. Peters *et al.*

(1982) reports likewise results finding breed differences in coat type to be highly significant (P<0.001).

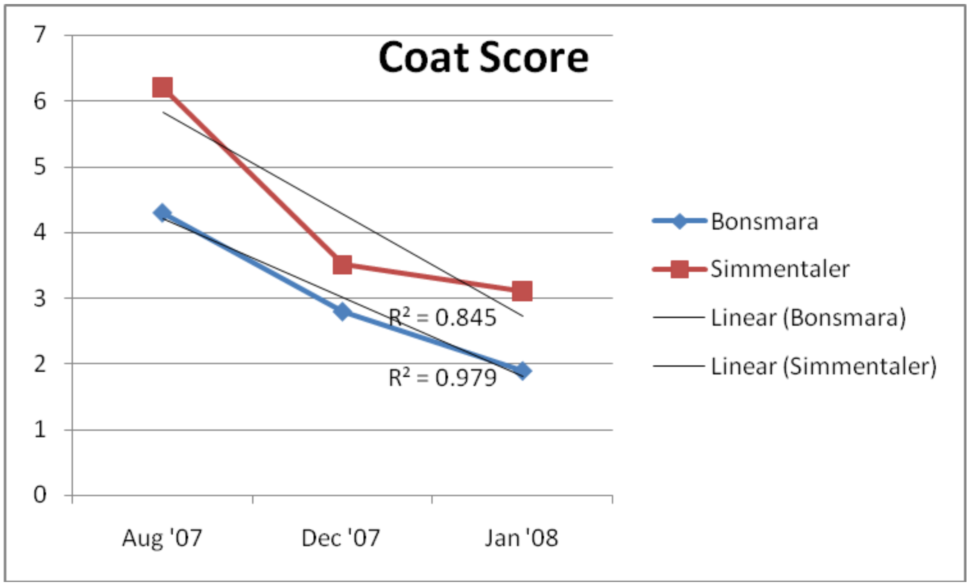

Figure 2: Mean coat scores for Bonsmara and Simmentaler heifers

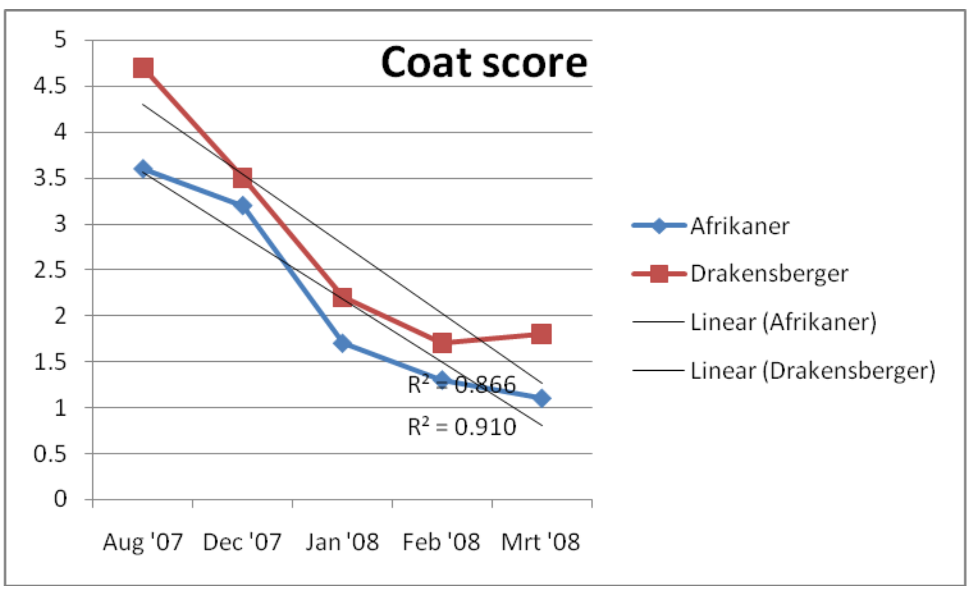

Figure 3: Mean coat scores for Afrikaner and Drakensberer heifers

The mean coat scores and R^2 taken from August 2007 to January 2008 for the Bonsmara and Simmentaler heifers are presented in figure 2. In Figure 3 and 4 coat score and R^2 taken from August 2007 to March 2008 for the Afrikaner, Braford, Drakensberger and Charolais heifers are illustrated.

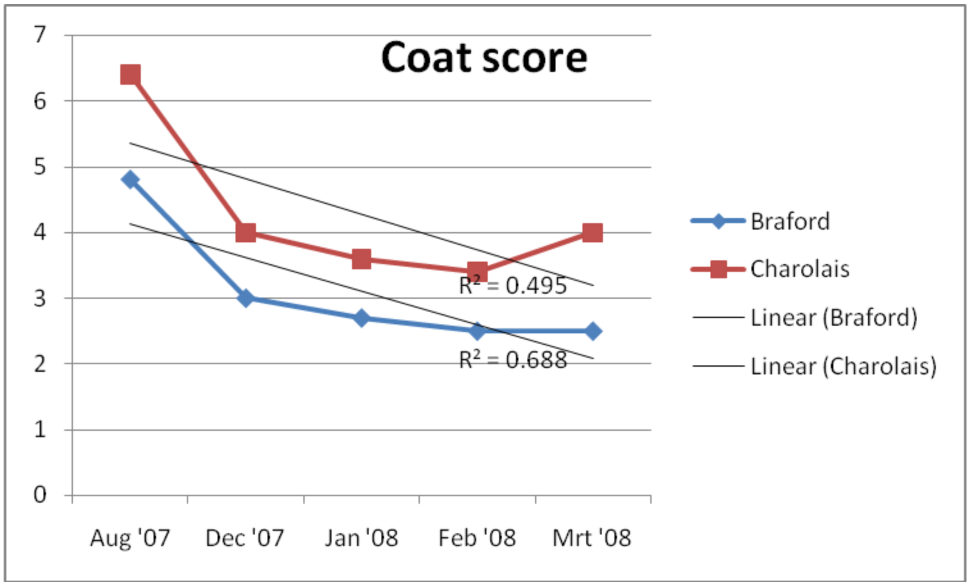

Figure 4: Mean coat scores for Braford and Charolais heifers

When studying the relationship between coat score and rectal temperature, only the Charolais heifers' coat scores had a significant ($P < 0.05$) influence on their rectal temperatures in summer. The other breeds' rectal temperatures were not affected by coat score. Prayaga (2003) did not observe any correlation between rectal temperatures and coat scores in Zebu cross, Zebu, Sanga-derived and Continental beef breeds. However he did observe a significant positive correlation between rectal temperature and coat scores in British purebreds.

Turner and Schleger (1960) established that coat score was effected by season, age, sex, pregnancy and lactation, nutrition, breed and individual differences, but that the greatest contribution to the differences in coat score being breed.

Prayaga *et al.* (2009) found the heritability of coat score to be high (>50%). The negative correlations between coat scores and body-condition score across genotypes (-0.33 to -0.44) indicated genetic advantage of sleek coats in the tropics. A positive genetic correlation between coat scores and age at first observed corpus luteum (0.73) in Brahman indicated that Brahman with sleeker coats were genetically early maturing.

It has been suggested by Dowling (1956) that differences in temperature tolerance may, through the condition of the animal, be the cause of coat differences, the cattle that do not thrive failing to shed their coats. Peters *et al*. (1982) reported that an unfavourable coat type did not have a negative effect on growth rate and that coat type was not so much the cause of weight gain but rather its result.

4.4 Body Condition Score

Mean BCS data are summarised in Table 10. The BCS were assessed in the first week of January, February and March of 2008. The Bonsmara and Simmentaler heifers had to be withdrawn from the research as they where to be bred at an age of 18 months and as a consequence had to be returned to their owners resulting in only one measurement taken for BCS for these two breeds.

Table10: Least-squares means (± s.e.) for body condition score (BCS) per breed with a value of 1 being thin and 9 obese

Para-meter	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
BCS 1	6.4 ± 0.16^{ab}	6.4 ± 0.16^{ab}	6.9 ± 0.10^{a}	5.4 ± 0.16^{c}	6.2 ± 0.13^{b}	5.9 ± 0.10^{bc}
BCS 2	7.0 ± 0.00^{a}	-	7.0 ± 0.00^{a}	5.6 ± 0.16^{b}	6.8 ± 0.13^{a}	-
BCS 3	7.0 ± 0.00^{a}	-	7.9 ± 0.31^{b}	5.3 ± 0.15^{c}	6.9 ± 0.10^{a}	-

[1]Means in the same row with different superscript letters differ significantly: $P < 0.0001$.

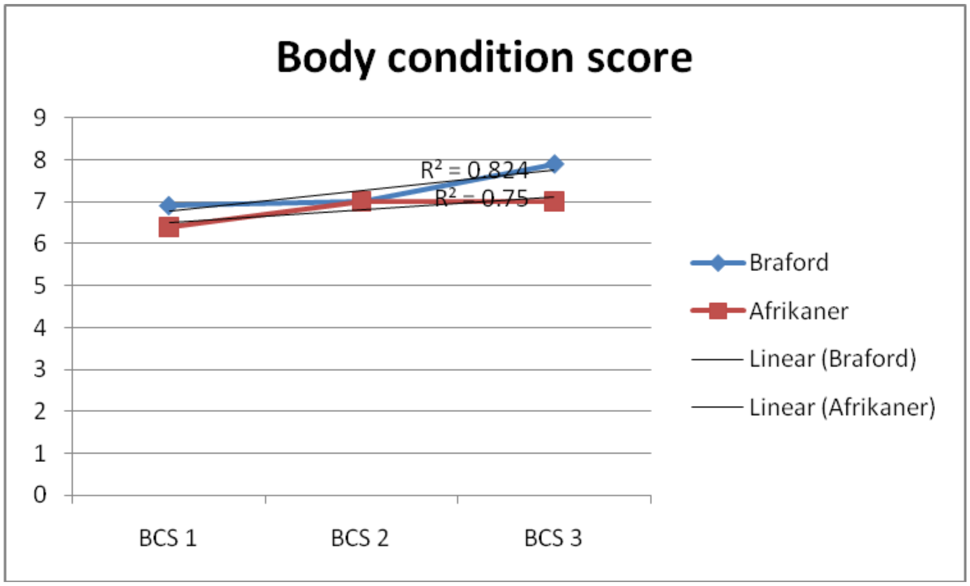

Figure 5: Mean body condition scores for Afrikaner and Braford heifers

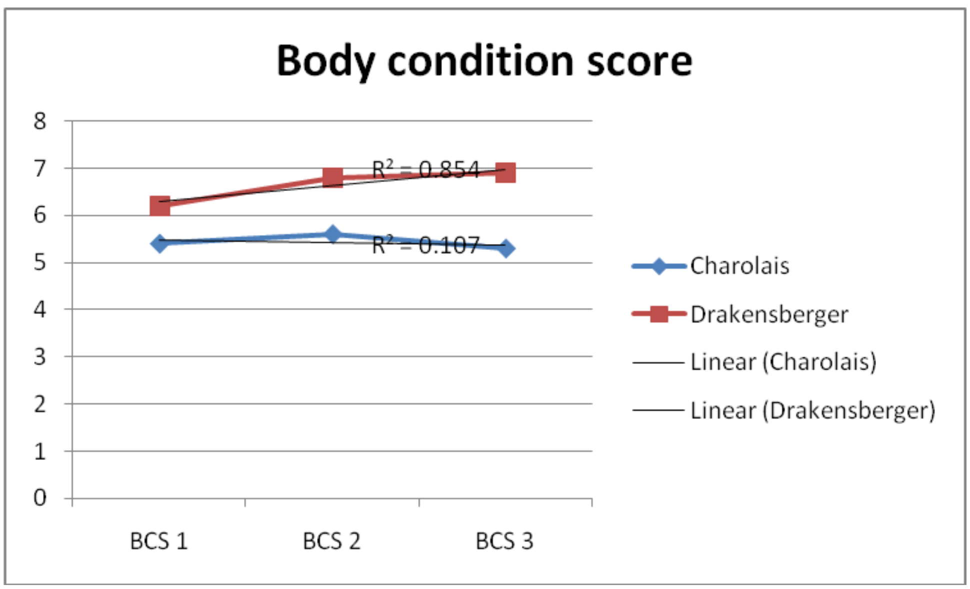

Figure 6: Mean body condition scores for Charolais and Drakensberger heifers

The mean BCS and R^2, measured on three occasions, for the Afrikaner and Braford heifers are presented in Figure 5 and the BCS and R^2 for the Charolais and Drakensberger heifers are illustrated in fig. 6.

Highly significant ($P < 0.0001$) breed differences in body condition scores were reported throughout the course of the study. The Braford heifers had the highest mean BCS and the Charolais heifers' the lowest mean BCS throughout the duration of the research. The Charolais heifers BCS was significantly lower than that of the Afrikaner, Braford, and Drakensberger heifers. No significant differences in BCS were observed between the Afrikaner and Drakensberger heifers on all three sampling events.

On the basis of mean BCS, the breeds have been ranked in order of decreasing BCS as Braford > Afrikaner, Bonsmara, Drakensberger > Simmentaler > Charolais. The body condition scores of the heifers did not have any significant influence on the heifers' rectal temperatures. However Prayaga *et al.* (2009) found that scanned fat measures at rump and rib sites for feedlot steers showed strong genetic correlation (0.50-0.58) with heifers' rectal temperatures, indicating genetically fatter animals had genetically lower heat tolerance. In Brahman, a positive genetic association between coat colour and scanned fat measures in steers (0.50-0.54) implied increased fatness in genetically darker animals.

Body condition scores (BCS) are a subjective measure of body fat and tissue reserves that are commonly used to monitor and manage the nutritional and health status of cattle herds (Dechow *et al*., 2001). BCS is an effective tool for cattle producers who do not weigh cattle and it may even surpass the measurement of cow weight in improving reproductive performance (Dechow *et al*., 2001). Most studies show that body condition decreases at a faster rate than weight loss (Rossi and Wilson, 2006). Dechow *et al.* (2001) report that the lower limit of a healthy cow's body condition level may be under greater genetic control, whereas condition levels above lower limit, are influenced to a greater extent by management and environmental conditions.

Fat is a metabolic tissue and primarily an energy store, but can act as an insulator against heat loss under cutaneous and subcutaneous vasoconstriction. Subcutaneous fat has little insulating effect under vasodilation of the peripheral region (Maree & Casey, 1993). The adapted indigenous livestock of southern Africa are early maturing, depositing fat, often localised, at an earlier age and lower body weight than late-maturing exogenous stock. The localisation of fat, such as in the desert adapted sheep, is often ascribed to heat adaptation as it leaves the rest of the body relatively fat free, particularly the subcutaneous depot, to facilitate heat exchange. Early maturity may favour adaptability, but the low relative weight gain is not advantageous to semi-intensive and intensive production systems. Selecting for leanness or for improved weight gain is selecting against early maturity and possibly against adaptability (Maree & Casey, 1993).

4.5 Hide thickness

Table 11 summarises the results of the mean hide thickness in millimetre (mm) per breed. The hide thicknesses were measured in August and December 2008 and January and March of 2009. The Bonsmara and Simmentaler heifers had to be withdrawn from the research as they where to be bred at an age of 18 months and as a consequence had to be returned to their owners. This resulted in only two measurements for hide thickness taken for these two breeds.

Table 11: Least-squares means (±s.e.) for hide thickness measured in millimetres per breed

Parameter	**Afrikaner (*n*=10)**	**Bonsmara (*n*=10)**	**Braford (*n*=10)**	**Charolais (*n*=10)**	**Drakensberger (*n*=10)**	**Simmentaler (*n*=10)**
H 1	14.1 ± 0.52^{a}	12.6 ± 0.60^{ab}	12.8 ± 0.51^{ab}	8.0 ± 0.30^{c}	11.5 ± 0.43^{b}	11.4 ± 1.38^{b}
H 2	14.6 ± 0.47^{a}	12.4 ± 0.52^{b}	12.6 ± 0.43^{b}	7.9 ± 0.43^{c}	11.0 ± 0.49^{b}	12.1 ± 0.77^{b}
H 3	16.4 ± 0.16^{a}	-	14.5 ± 0.54^{b}	10.4 ± 0.40^{c}	13.4 ± 0.31^{b}	-

[1]Means in the same row with different superscript letters differ significantly: $P < 0.0001$

Highly significant ($P < 0.0001$) differences in hide thicknesses were found between breeds. The Afrikaner heifers had the thickest hide throughout course of the research and the Charolais heifers the thinnest hide. No significant differences in hide thicknesses were measured between the Bonsmara, Braford, Drakensberger and

Simmentaler heifers. Hide thickness only had a significant influence ($P< 0.05$) on rectal temperature in the Afrikaner and Bonsmara heifers.

These results contradict research done by Spickett *et al*. (1989) that found no significant difference in double skin thickness' between the Nguni, Bonsmara and Hereford breeds or between sexes of the same breeds and thus no correlation between skin thickness and tick resistance could be determined.

Bonsma (1983) however found that the adapted Afrikaner breed had a much thicker hide than Shorthorns and where skin fold thicknesses on thousands of animals were taken over a period of 23 years, he found that indigenous Afrikaner cattle (*Bos indicus*) had appreciably thicker hides than British beef breeds. Present research done emulates research done by Bonsma (1983) in that the Afrikaner heifers consistently had significantly thicker hides of respectively 14.1 mm, 14.6 mm and 16.4 mm compared to the hide thickness of the Charolais heifers of 8.0 mm, 7.9 mm and 10.4 mm.

In Figure 7 breed as well seasonal difference in hide thicknesses are clearly illustrated.

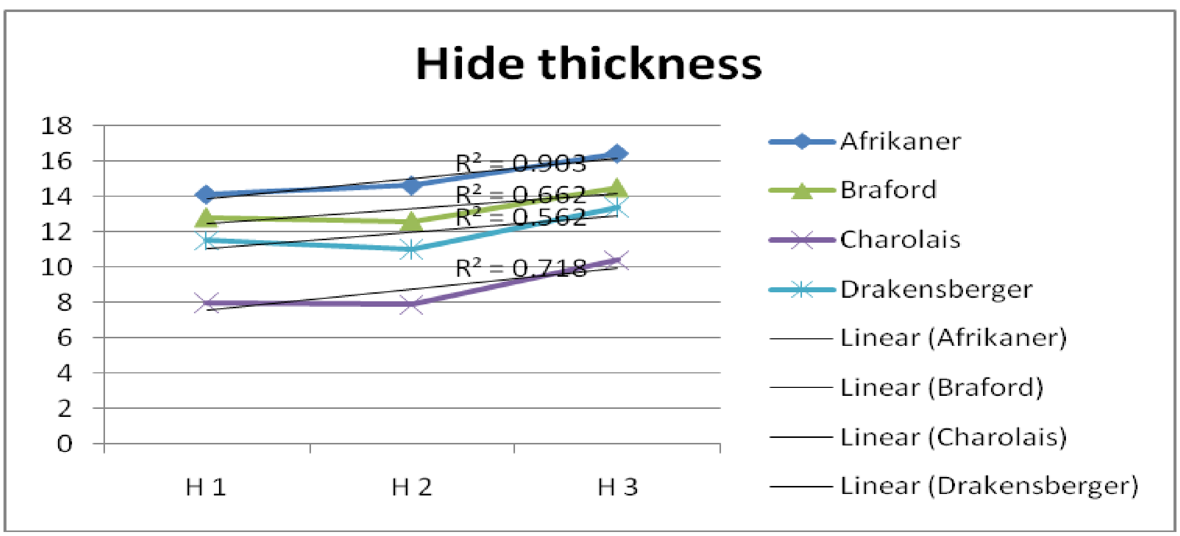

Figure 7: Mean hide thickness per breed measured in mm

4.6 Tick count

The heifers were allowed to become naturally infested with ticks. Two officers, one on either side, carefully examined the restrained animals, recording all visible ticks. Tick burdens were determined on five occasions during February 2008 on the Afrikaner, Braford, Charolais and Drakensberger. The average tick counts per breed are reflected in Table 12.

Table 12: Least-squares means (± s.e.) for tick counts (T) per breed

Parameter	Date	Afrikaner (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)
T 1	06-02-2008	12.3 ± 1.71[a]	20.2 ± 2.70[a]	36.2 ± 2.58[b]	18.2 ± 1.74[a]
T 2	13-02-2008	9.0 ± 1.04[a]	14.9 ± 2.64[a]	24.7 ± 3.00[b]	14.1 ± 1.72[a]
T 3	20-02-2008	9.6 ± 0.83[a]	15.9 ± 1.35[ab]	21.9 ± 2.34[b]	14.0 ± 1.77[a]
T 4	27-02-2008	13.4 ± 1.43[a]	21.6 ± 1.78[bc]	27.1 ± 2.90[c]	17.2 ± 2.15[ab]
T 5	05-03-2008	15.1 ± 1.48[a]	21.7 ± 2.21[ab]	26.2 ± 1.57[b]	17.7 ± 1.83[a]

[1]Means in the same row with different superscript letters differ significantly: $P < 0.001$

Table 12 summarises the results of mean tick counts per breed over five appraisals. Across all measurements the Afrikaner heifers had the least ticks and the Charolais heifers the most ticks with the significant difference in tick count between these breeds being $P < 0.001$. No significant differences in tick counts were observed between the Afrikaner and Drakensberger heifers as well as the Braford and Drakensberger heifers. The mean tick counts did not have any significant influence on the rectal temperatures of the heifers. On the basis of mean tick count, the breeds have been ranked in order of decreasing resistance to ticks as Afrikaner, Drakensberger > Braford > Charolais.

Figure 8 clearly indicates the difference in tick infestations between breeds over all five sampling days.

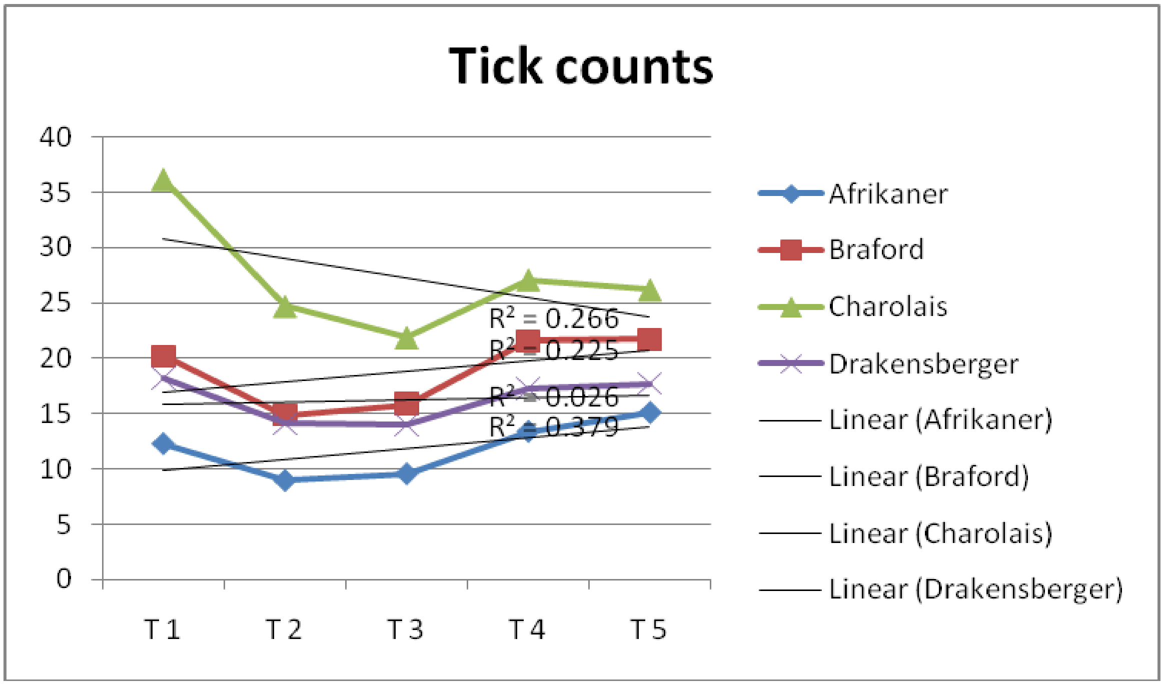

Figure 8: Mean number of ticks per breed over time

In the present study, the indigenous Afrikaner and Drakensberger breeds had a lower tick infestation compared to the Braford and Charolais heifers. Spickett *et al.* (1989) showed likewise results in that the indigenous Nguni breed harboured significantly fewer ticks during periods of peak abundance than either Bonsmara or Hereford cattle. Frisch and O'Neill (1998) ranked the Charolais sire breed last for tick resistance thus corroborating present research.

Observations made on undipped cattle infected with *Boophilus microplus* ticks in Central Queensland established that Zebu crosses were infected to a significantly lesser degree and this phenomenon was attributed to the Zebu cattle's thicker skins (Bonsma, 1983). Bonsma states that ticks prefer to infest cattle on the body areas where the skin is significantly thinner and where they are protected from direct solar radiation. He observed that Afrikaner cattle were only 30 percent infested in comparison to 70 percent in the British breeds and that in summer, Afrikaner cattle carried only 8 percent of the tick population of British breeds and in winter 40 percent. The present research parallels Bonsma's findings in that the Afrikaner heifers constantly harboured the least ticks. Bonsma ascribes one of the reasons for the lesser tick infestations on the Afrikaner cattle their significantly thicker hides (Bonsma, 1983).

Prayaga & Henshall (2005) found that the genetic correlations among tick counts, faecal egg counts and rectal temperatures were moderately positive, suggesting that closely-linked genes affect these adaptive traits.

While evaluating the resistance of beef cattle breeds of African, European, and Indian origins to ticks Frisch and O'Neill (1998) found that even while low tick infestations were reported during their research, the regression of live-weight gains on tick counts was about 0.5 kg per tick per year for each genotype.

4.7 Respiration Rate (R_r)

The respiration rate was observed on eleven separate events or days. The respiration (R_r) rate between breeds differed significantly only on three days, namely the second, seventh and tenth day of observation, on the remaining eight days no significant differences in respiration rates were observed between breeds. On the three days where significant differences in respiration rates were observed the Drakensberger heifers had the lowest respiration rate at an average of 41.6, 36.4 and 35.6 breaths per minute respectively and the Braford heifers the highest at 54.8, 51.2 and 63.6 breaths per minute. On the first occurrence (second day of measurement) where significant ($P < 0.01$) differences in respiration rates were detected, the Braford and Afrikaner heifers respiration rates were significantly faster than that of the Drakensberger heifers, but did not differ significantly from the Bonsmara, Charolais and Simmentaler heifers respiration rates. However the Drakensberger heifer's respiration rate was not significantly slower than that of the Bonsmara, Charolais, and Simmentaler heifers. On the second occasion (seventh day of measurement) where significant differences ($P < 0.1$) in respiration rates between breeds were observed the Braford heifers respiration rate was significantly faster than that of the Drakensberger heifers, but not significantly faster than that of the Afrikaner and

Charolais heifers. On the last occasion (tenth day of measurement) where differences in respiration rates were observed the Braford heifers respiration rates were significantly (P < 0.0001) faster than that of the Afrikaner, Charolais and Drakensberger heifers.

The Bonsmara and Simmentaler heifers had to be withdrawn from the research due to conflicting breeding programmes and as a result only five measurements for respiration rate were taken for these two breeds. The mean respiration rates per breed for each of the eleven measurement events are presented Table 13.

Table 13: Least-squares means[1] and s.e of respiration rates (R_r) per breed

Para-meter	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
R_r 1	49.6 ± 3.10^a	43.6 ± 2.56^a	48.0 ± 4.26^a	46.0 ± 4.10^a	39.2 ± 2.04^a	44.4 ± 2.27^a
R_r 2	53.2 ± 2.67^a	48.4 ± 2.76^{ab}	54.8 ± 3.04^a	50.0 ± 2.33^{ab}	41.6 ± 2.00^b	51.6 ± 2.34^{ab}
R_r 3	49.2 ± 2.92^a	44.8 ± 1.77^a	49.6 ± 2.17^a	48.4 ± 2.70^a	42.4 ± 2.40^a	48.8 ± 3.20^a
R_r 4	52.8 ± 3.47^a	46.8 ± 3.27^a	51.2 ± 4.04^a	49.6 ± 5.17^a	40.0 ± 2.98^a	48.8 ± 3.14^a
R_r 5	50.8 ± 6.05^a	44.8 ± 2.44^a	49.2 ± 3.82^a	46.0 ± 3.56^a	44.8 ± 4.29^a	39.6 ± 2.27^a
R_r 6	43.6 ± 3.01^a	-	45.2 ± 3.10^a	39.2 ± 2.58^a	36.4 ± 2.79^a	-
R_r 7	43.2 ± 3.03^{ab}	-	51.2 ± 5.23^a	43.2 ± 2.72^{ab}	36.8 ± 2.52^b	-
R_r 8	48.4 ± 3.89^a	-	53.6 ± 5.76^a	44.8 ± 3.31^a	40.4 ± 2.42^a	-
R_r 9	38.8 ± 2.92^a	-	40.0 ± 3.53^a	36.4 ± 2.34^a	34.4 ± 2.17^a	-
R_r 10	44.6 ± 3.63^a	-	63.6 ± 5.38^b	43.2 ± 3.26^a	35.6 ± 2.42^a	-
R_r 11	46.0 ± 4.55^a	-	44.8 ± 3.81^a	38.0 ± 2.62^a	34.4 ± 2.08^a	-

[1]Means in the same row with different superscript letters differed significantly:
R_r 2 (P < 0.01), R_r 7 (P < 0.1), R_r 10 (P < 0.0001)

The susceptibility of certain genotypes such as the Charolais to heat stress was not evident through enhanced respiration rate as no relationship between respiration rate and rectal temperatures were found. Compared to other genotypes, the lower respiration rate of the Drakensberger heifers was evident however the cause of the lower respiration rate could not be explained.

Under extremely hot conditions (THI > 90), evaluated in a climatically controlled room, Gaughan *et al.* (1999) found that purebred Brahman (B) had a significantly ($P < 0.05$) lower rectal temperature and respiration rate than other genotypes. The respiration rate of Hereford (H) x B were intermediate. However, in these extreme conditions, respiration rate did not differ significantly among purebred H and the Boran and Tuli crossbred steers, but H x B steers had lower respiration rates than the other H crossbred steers. In summer environmental conditions (similar to present study) the respiration rates increased over time for Hereford only, and respiration rates for other genotypes tended to be elevated only slightly over time.

Research done by Bennett *et al.* (1984) found that respiration rate made a significant contribution to the variance accounted for in both time spent in the shade in the shade-yard and at pasture. The Shorthorn steers spent most time in shade and the least time grazing compared to Brahman and Brahman x Shorthorn-Hereford cross steers, indicating that they were most heat stressed. The results suggest that shade use and respiration rate could be simple and effective methods to select heat tolerant animals in the tropics.

4.8 Body (rectal) temperatures (RT) in winter

Heat tolerance was evaluated under summer environment conditions by comparing rectal temperatures. As a climatically controlled room was not available for a control group it was decided to record rectal temperatures in winter and in summer.

The prevailing weather conditions at the time of measurement of rectal temperatures in August 2007 (winter) are given in Table 14.

Table 14: Winter weather data for August 2007

Day	Time	Temp (°C)	Wet bulb temp (°C)	Humidity (%)	Wind (km/h)	LWSI
1	14:00	20	6	7	20	66
2	14:00	10	3	41	12	53
3	14:00	18	8	29	30	63
4	14:00	15	8	43	14	58
5	14:00	19	8	21	17	64
6	14:00	10	2	28	20	53
7	14:00	13	5	26	13	57
8	14:00	17	5	12	6	62
9	14:00	24	8	9	8	70
10	14:00	26	8	5	8	74

The mean winter rectal temperatures for each breed measured on 10 occasions are presented in Table 15.

Table 15: Least squares means[1] and s.e for rectal temperatures (RT) in winter per breed

Parameter	Afrikaner *(n=10)*	Bonsmara *(n=10)*	Braford *(n=10)*	Charolais *(n=10)*	Drakensberger *(n=10)*	Simmentaler *(n=10)*
RT1	39.55 ± 0.05[a]	39.66 ± 0.10[a]	39.72 ± 0.18[a]	39.49 ± 0.06[a]	39.31 ± 0.08[a]	39.43 ± 0.10[a]
RT2	38.84 ± 0.05[a]	39.20 ± 0.10[b]	38.85 ± 0.08[abc]	39.10 ± 0.09[bc]	38.70 ± 0.07[a]	38.85 ± 0.12[abc]
RT3	39.27 ± 0.11[a]	39.27 ± 0.10[ab]	39.23 ± 0.12[ab]	39.19 ± 0.06[ab]	38.87 ± 0.05[b]	39.02 ± 0.11[ab]
RT4	38.98 ± 0.11[ab]	39.23 ± 0.10[a]	39.04 ± 0.08[ab]	39.18 ± 0.06[ab]	38.89 ± 0.04[b]	39.20 ± 0.07[ab]
RT5	39.25 ± 0.10[a]	39.37 ± 0.09[a]	39.15 ± 0.12[a]	39.27 ± 0.14[a]	39.07 ± 0.12[a]	39.20 ± 0.07[a]
RT6	38.82 ± 0.12[a]	39.09 ± 0.19[ab]	38.96 ± 0.10[a]	39.72 ± 0.22[b]	38.72 ± 0.10[a]	39.24 ± 0.25[ab]
RT7	39.07 ± 0.08[a]	39.13 ± 0.06[a]	39.24 ± 0.13[a]	40.29 ± 0.29[b]	38.93 ± 0.08[a]	39.38 ± 0.29[a]
RT8	39.24 ± 0.11[a]	39.59 ± 0.16[a]	39.57 ± 0.22[a]	39.88 ± 0.18[a]	39.28 ± 0.12[a]	39.34 ± 0.10[a]
RT9	39.54 ± 0.06[ab]	39.65 ± 0.12[ab]	39.69 ± 0.20[ab]	40.10 ± 0.24[a]	39.12 ± 0.07[b]	39.78 ± 0.27[ab]
RT10	39.48 ± 0.27[a]	39.34 ± 0.15[a]	39.10 ± 0.12[a]	39.52 ± 0.27[a]	38.88 ± 0.16[a]	39.74 ± 0.25[a]

[1]Means in the same row with different superscript letters differed significantly

As seen in Table 15, no significant differences ($P > 0.1$) in rectal temperatures between breeds were detected on the 1st, 5th, 8th, and 10th day of observation. On the second day (RT2) a significant difference ($P < 0.001$) in rectal temperatures was observed between breeds with the Drakensberger heifers having the lowest mean rectal temperature of 38.70°C ± 0.07 and the Bonsmara heifers the highest mean rectal temperature of 39.20°C ± 0.10. The Afrikaner and Drakensberger heifers' mean rectal temperatures were significantly ($P < 0.001$) lower than that of the Bonsmara and Charolais heifers' rectal temperatures. The Braford and Simmentaler heifers' mean rectal temperature did not differ significantly from any of the other breeds' rectal temperatures.

On the third day (RT3) of measurement the Afrikaner heifers had the highest mean rectal temperature of 39.27°C ± 0.11 and the Drakensberger heifers the lowest mean rectal temperature of 38.87°C ± 0.05 with the significance being $P < 0.1$. The Bonsmara, Braford, Charolais and Simmentaler heifers' mean rectal temperatures did not differ significantly from either the Afrikaner or the Drakensberger heifers' mean rectal temperatures.

On the fourth day (RT4) the Bonsmara had the highest mean rectal temperature of 39.23°C ± 0.10 and the Drakensberger heifers the lowest mean rectal temperature of 38.89°C ± 0.04 with the significance being at a level of $P < 0. 1$. The Afrikaner, Braford, Charolais and Simmentaler heifers' mean rectal temperatures did not differ significantly from either the Bonsmara or the Drakensberger heifers' mean rectal temperature.

On the sixth day (RT6) significant ($P < 0.01$) differences in mean rectal temperatures between breeds were detected with the Charolais heifers having the highest mean rectal temperature of 39.72°C ± 0.22 and the Drakensberger heifers having the lowest mean rectal temperature of 38.72°C ± 0.10. The Afrikaner, Braford and Drakensberger heifers' rectal temperatures differed significantly ($P < 0.01$) from the Charolais heifers' mean rectal temperature. The Bonsmara and Simmentaler heifers' mean rectal temperature did not differ significantly from the other four breeds in the study.

On the seventh day (RT7) the Drakensberger heifers had the lowest mean rectal temperature of 38.93°C ± 0.08 and the Charolais heifers the highest mean RT of 40.29°C ± 0.29. Highly significant ($P < 0.001$) differences in rectal temperatures were observed between the Charolais and rest of the breeds. No significant differences in mean rectal temperatures were measured between the Afrikaner, Bonsmara, Braford, Drakensberger and Simmentaler heifers.

On the ninth day (RT9) the Charolais heifers had the highest mean rectal temperature of 40.10°C ± 0.24 and the Drakensberger heifers the lowest at 39.12°C ± 0.07 with the significance being $P < 0.1$. The Afrikaner, Bonsmara, Braford and Simmentaler heifers' mean rectal temperatures did not differ significantly from either the Charolais or Drakensberger heifers mean rectal temperature.

On all six days where significant differences in rectal temperatures between breeds were measured the Drakensberger heifers had the lowest mean rectal temperature. The Charolais heifers on the other hand had significantly higher rectal temperatures than the other breeds on four of the six days.

In Table 16 a summary of the results of the rectal temperatures measured in winter are given. The rectal temperatures of breeds in column A differ significantly from the rectal temperatures of the breeds in Column C but not from the breeds in Column B. Similarly, the breeds in Column C's rectal temperatures differ significantly from breeds in Column A's rectal temperatures but not from breeds in Column B.

Table 16: Summary of the results of rectal temperatures taken in winter

	A	B	C
Day	**Breeds with a significantly lower RT than breeds in column C**	**Breeds with no significant difference in RT from breeds either in column A or C**	**Breeds with a significantly higher RT than breeds in column A**
1		Afrikaner, Bonsmara, Braford, Charolais, Drakensberger, Simmentaler	
2	Afrikaner, Drakensberger	Braford, Simmentaler	Bonsmara, Charolais
3	Drakensberger	Bonsmara, Braford, Charolais, Simmentaler	Afrikaner
4	Drakensberger	Afrikaner, Braford, Charolais, Simmentaler	Bonsmara
5		Afrikaner, Bonsmara, Braford, Charolais, Drakensberger, Simmentaler	
6	Afrikaner, Braford, Drakensberger	Bonsmara, Simmentaler	Charolais
7	Afrikaner, Bonsmara Braford, Drakensberger, Simmentaler		Charolais
8		Afrikaner, Bonsmara, Braford, Charolais, Drakensberger, Simmentaler	
9	Drakensberger	Afrikaner, Bonsmara Braford, Simmentaler	Charolais
10		Afrikaner, Bonsmara, Braford, Charolais, Drakensberger, Simmentaler	

4.9 Body (rectal) temperatures (RT) in summer

The prevailing weather conditions at the time of measurement of the rectal temperatures in summer are given in Table 17. The summer section of the research was conducted from December 2007 to February 2008.

Table 17: Summer weather data

Month	Time	Temp (°C)	Wet bulb temp (°C)	Humidity (%)	Wind (km/h)	LWSI
Dec						
1	14:00	28	16	30	10	73
2	14:00	30	11	9	9	78
3	14:00	33	17	18	7	80
4	14:00	31	17	26	8	77
5	14:00	30	16	23	2	78
6	14:00	24	14	31	20	69
Jan						
7	14:00	24	13	35	5	69
8	14:00	26	17	48	5	70
9	14:00	30	16	36	17	76
10	14:00	32	19	34	6	78
11	14:00	34	17	20	5	81
12	14:00	33	15	26	5	80
Feb						
13	14:00	33	16	20	3	80
14	14:00	34	16	23	4	81
15	14:00	27	11	37	7	73
16	14:00	34	15	28	5	80
17	14:00	32	16	19	5	79

The summer section of the research will be discussed in two separate sections as the Bonsmara and Simmentaler heifers were withdrawn at the latter stages of the research. Section one consists of ten measurements in which all six breeds partook and section two seven measurements in which the Afrikaner, Braford, Charolais and Drakensberger participated.

The mean summer rectal temperatures for each breed are given in Table 18.

Table 18: Least squares means[1] and s.e for rectal temperature (RT) in summer per breed

Para-Meter	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
RT1	9.45 ± 0.18^{a}	39.39 ± 0.07^{a}	39.50 ± 0.17^{a}	39.60 ± 0.06^{a}	39.43 ± 0.09^{a}	39.40 ± 0.07^{a}
RT2	39.43 ± 0.20^{a}	39.34 ± 0.05^{a}	39.53 ± 0.21^{a}	39.44 ± 0.06^{a}	39.37 ± 0.09^{a}	39.59 ± 0.15^{a}
RT3	39.26 ± 0.09^{a}	39.23 ± 0.04^{a}	39.40 ± 0.15^{a}	39.56 ± 0.12^{a}	39.38 ± 0.17^{a}	39.59 ± 0.14^{a}
RT4	39.18 ± 0.08^{a}	39.20 ± 0.06^{a}	39.38 ± 0.13^{ab}	39.74 ± 0.18^{b}	39.26 ± 0.04^{a}	39.54 ± 0.08^{ab}
RT5	39.22 ± 0.09^{a}	39.52 ± 0.14^{ab}	39.57 ± 0.19^{ab}	39.81 ± 0.04^{b}	39.56 ± 0.06^{ab}	39.72 ± 0.09^{b}
RT6	38.88 ± 0.14^{a}	39.01 ± 0.05^{ab}	38.95 ± 0.05^{ab}	39.30 ± 0.10^{b}	38.95 ± 0.07^{ab}	39.26 ± 0.06^{b}
RT7	38.79 ± 0.58^{a}	38.93 ± 0.05^{ab}	38.85 ± 0.05^{a}	39.25 ± 0.04^{c}	38.85 ± 0.06^{a}	39.11 ± 0.07^{bc}
RT8	38.91 ± 0.04^{a}	39.00 ± 0.05^{abc}	38.99 ± 0.10^{ab}	39.21 ± 0.03^{bc}	38.90 ± 0.07^{a}	39.26 ± 0.07^{c}
RT9	39.06 ± 0.05^{a}	39.07 ± 0.05^{a}	38.96 ± 0.06^{a}	39.37 ± 0.05^{b}	39.13 ± 0.06^{ab}	39.36 ± 0.08^{b}
RT10	39.31 ± 0.08^{ab}	39.51 ± 0.15^{ab}	39.17 ± 0.06^{a}	39.74 ± 0.13^{b}	39.34 ± 0.11^{ab}	39.56 ± 0.07^{ab}
RT11	39.18 ± 0.09^{a}	-	39.16 ± 0.07^{a}	39.47 ± 0.04^{b}	39.20 ± 0.03^{a}	-
RT12	39.03 ± 0.05^{a}	-	38.97 ± 0.05^{a}	39.41 ± 0.05^{b}	39.04 ± 0.05^{a}	-
RT13	39.08 ± 0.04^{a}	-	39.09 ± 0.07^{a}	39.56 ± 0.06^{b}	39.09 ± 0.04^{a}	-
RT14	39.11 ± 0.06^{a}	-	39.05 ± 0.07^{a}	39.72 ± 0.08^{b}	38.98 ± 0.05^{a}	-
RT15	39.11 ± 0.05^{a}	-	38.95 ± 0.06^{a}	39.55 ± 0.06^{b}	39.04 ± 0.07^{a}	-
RT16	38.96 ± 0.13^{a}	-	39.35 ± 0.23^{a}	39.60 ± 0.25^{a}	39.03 ± 0.10^{a}	-
RT17	39.00 ± 0.10^{ab}	-	38.83 ± 0.06^{a}	39.21 ± 0.05^{b}	38.97 ± 0.15^{ab}	-

[1]Means in the same row with different superscript letters differed significantly

On the first three observation days no significant differences between breeds with regards to mean rectal temperatures between breed were observed.

On the fourth day (RT4) of measurement the Afrikaner heifers had the lowest mean rectal temperature of 39.18°C ± 0.08 and the Charolais heifers the highest mean RT of 39.74°C ± 0.18 with the significance being $P < 0.01$. The Afrikaner, Bonsmara, and Drakensberger heifers had significantly lower mean rectal temperatures than the Charolais heifers. The Braford and Simmentaler heifers' mean RT did not differ significantly from the Afrikaner, Bonsmara, Drakensberger or Charolais heifers.

On the fifth and sixth day of measurement identical results were observed. The Charolais and Simmentaler heifers had significantly ($P < 0.01$) higher mean rectal temperatures than the Afrikaner heifers. The Bonsmara, Braford and Drakensberger heifers' mean rectal temperatures did not differ significantly from the Charolais, Simmentaler and Afrikaner heifers' rectal temperatures.

On day seven the Afrikaner heifers had the lowest mean rectal temperature of 38.79°C ± 0.58 with the Charolais having the highest rectal temperature of 39.25°C ± 0.04. No significant differences in mean rectal temperatures were observed between the Afrikaner, Bonsmara, Braford and Drakensberger breeds. The Charolais heifers' mean rectal temperature was significantly ($P < 0.0001$) higher than that of the Afrikaner, Bonsmara, Braford and Drakensberger heifers' mean rectal temperatures, but was not significantly higher than that of the Simmentaler heifers mean rectal temperature.

On the eighth day the Drakensberger heifers had the lowest mean rectal temperature of 38.90 ± 0.07 and Simmentaler heifers the highest mean rectal temperature of 39.26 ± 0.07 with the significance being $P < 0.001$. No significant differences in mean rectal temperatures were observed between the Afrikaner and Drakensberger heifers. The Simmentaler heifers' mean rectal temperature was not significantly higher than that of the Braford or Charolais heifers' mean rectal temperature. No significant difference in mean rectal temperature was detected between the Bonsmara and the other breeds.

On the ninth day of observation the Braford heifers had the lowest mean rectal temperature of 38.96°C ± 0.06 and the Simmentaler heifers the highest mean rectal temperature of 39.36°C ± 0.08 and the significance being $P < 0.0001$. No significant differences in mean rectal temperatures were measured between the Afrikaner, Bonsmara and Braford heifers as well as between the Charolais and Simmentaler heifers. The Drakensberger heifers' mean rectal temperature did not differ significantly from any of the breeds.

On day ten the Braford heifers had the lowest mean rectal temperature of 39.17 ± 0.06 and the Charolais heifers the highest mean rectal temperature of 39.74°C ± 0.13 with the significance being $P < 0.01$. The Afrikaner, Bonsmara Drakensberger and Simmentaler heifers' mean rectal temperature did not differ significantly from either the Braford or the Charolais heifers' mean rectal temperature.

As mentioned, in section two of the summer-research the Bonsmara and Simmentaler heifers did not participate. From the 11^{th} to the 16^{th} day of observation identical results were obtained. On all six occasions the Charolais heifers' mean rectal temperatures were significantly higher than that of the Afrikaner, Braford and Drakensberger heifers' mean rectal temperatures. No significant differences in mean rectal temperatures were observed between the Afrikaner, Braford and Drakensberger heifers. On the eleventh day the significant difference in mean RT between breeds was $P < 0.01$, the twelfth to the fifteenth day the significance was $P < 0.0001$ and the sixteenth day of observation the significant difference in mean rectal temperature between breeds was $P < 0.1$.

On the seventeenth day of the research the Charolais heifers had the highest mean RT of 39.21°C ± 0.05 and the Braford heifers the lowest mean rectal temperature of 38.83°C ± 0.06 and the significance being $P < 0.1$. No significant difference in mean rectal temperature was observed between the Afrikaner and Drakensberger heifers. The Afrikaner and Drakensbergers heifers' mean rectal temperature did not differ significantly from either the Braford or Charolais heifers.

The summer section of the research comprised of seventeen days of measurements and a significant difference in mean rectal temperature between breeds was observed on fourteen of the seventeen days.

Table 19 provides a summary of the results of the rectal temperatures measured in summer. The rectal temperatures of breeds in column A differ significantly from the rectal temperatures of the breeds in Column C but not from the breeds in Column B. Similarly, the breeds in Column C's rectal temperatures differ significantly from breeds in Column A's rectal temperatures but not from breeds in Column B.

Table 19: Summary of results of summer section of research

	A	B	C
Day	**Breeds with a significantly lower RT than breeds in column C**	**Breeds with no significant difference in RT from breeds either in column A or C**	**Breeds with a significantly higher RT than breeds in column A**
1 – 3		Afrikaner, Bonsmara, Braford, Charolais, Drakensberger, Simmentaler,	
4	Afrikaner, Bonsmara, Drakensberger	Braford, Simmentaler	Charolais
5 – 6	Afrikaner	Bonsmara, Braford, Drakensberger	Charolais, Simmentaler
7	Afrikaner, Bonsmara, Braford, Drakensberger		Charolais, Simmentaler
8	Afrikaner, Drakensberger	Bonsmara	Braford, Charolais, Simmentaler
9	Afrikaner, Bonsmara, Braford	Drakensberger	Charolais, Simmentaler
10	Braford	Afrikaner, Bonsmara Drakensberger, Simmentaler	Charolais
11 – 16	Afrikaner, Braford, Drakensberger		Charolais
17	Braford	Afrikaner, Drakensberger	Charolais

As mentioned during the first section of the summer research all six breeds partook in the research and rectal temperature measurements were taken on all the heifers on ten occasions. On five of the ten days the Charolais and Simmentaler heifers had significantly higher rectal temperatures than the Afrikaner heifers.

During the second section of the research in summer rectal temperature measurements were taken on all the Afrikaner, Braford, Charolais, and Drakensberger heifers on seven occasions. On six of the seven days the Charolais had significantly higher rectal temperatures than the Afrikaner, Braford and Drakensberger heifers.

Compared with other breeds, the higher RT of the Charolais and Simmentaler heifers was clearly evident and is assumed that these breeds are not as heat tolerant as the other breeds in the study. The lower rectal temperatures of the Bonsmara, Braford, Drakensberger and especially the Afrikaner are indicative of a superior ability to dissipate heat to maintain a lower rectal temperature. These findings are in agreement with Gaughan *et al.* (1999); Prayaga & Henshall (2005) and Prayaga *et al.* (2009).

4.10 Correlations between parameters

4.10.1 Hide thickness and tick count

Hide thickness, which is regarded by Bonsma (1983) as a good indicator of tick resistance was highly negatively correlated (-0.69) to tick count. The significance of this correlation was high ($P < 0.0001$). Prayaga (2003) found that treatment to control ticks and worms resulted in significantly increased live weight gains in a majority of genotypes, highlighting the negative effect of parasite burdens.

4.10.2 Coat score and tick count

A highly positive (0.70) correlation between coat score and tick count indicated that heifers with sleeker coats harboured fewer ticks and were more resistant to tick infestations. The significance of the correlation was high ($P < 0.0001$).
The results of this study contradict results from a study done by Spickett *et al.* (1989) on the resistance of Nguni, Bonsmara and Hereford cattle to ticks in a Bushveld

region of South Africa. Spickett *et al.* (1989) could not find any correlation between tick infestations and hair length.

4.10.3 Coat score and body condition score

A negative correlation between coat score and body condition score across genotypes (-0.40) was found. This negative genetic correlation between coat score and body condition scores indicates a genetic advantage of a sleek coat in a hot environment (Prayaga *et al.* 2009). The significance of the correlation was high ($P < 0.005$). Prayaga *et al.* (2009) also found the correlation between coat score and body condition score to be negative (-0.33 to -0.48).

4.10.4 Coat score and weight gain

A positive correlation (0.33) between coat score in summer and total weight gain was observed with the significance being $P < 0.01$. The *Bos Taurus* breeds had higher coat scores as well as a higher weight gain compared to the other genotypes. Prayaga *et al.* (2009) reports that sleeker coats were genetically indicative of lower weight at puberty in Brahman heifers.

The winter coat scores were a better predictor of total weight gain as the correlation between the coat scores in winter and total weight gain was higher (0.48) than the correlation between coat score in summer and total weight gain. The significance was $P < 0.0001$.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A distinct advantage for the indigenous Afrikaner and Drakensberger as well as the synthetic Braford and Bonsmara in adaptation to environmental heat over the Simmentaler and Charolais, as demonstrated by lower rectal temperatures, was evident in this study. Further, genotype rather than phenotypical expressions such as coat colour and coat score were indicative of animal's heat tolerance properties.

While rectal temperature is generally a good index of heat tolerance, it is possible that two animals could achieve the same control of body temperature by different patterns of regulatory functions, which would entail different penalties to productivity.

Growth and weight gain in heifers generally differed among genotypes with the Afrikaner gaining significantly less weight than the other breeds. Frisch and Vercoe (1977) found that Brahman and Brahman-cross cattle regulated body temperature efficiently, and were heat tolerant, in that productivity was little reduced in a hot environment. However, in the absence of the stresses, including heat, to which they are adapted, they exhibit low heat production, low food intake and low growth rate. This low intensity of metabolism forms part of the complex of attributes that contributes to their heat tolerance but it also lowers inherent productivity. While the potential usefulness of selecting for low rectal temperature is pointed out, such selection could embrace an undesirable component of low metabolic rate and food intake.

In the meantime, combined selection for low rectal temperature and high productivity in the relevant environment should enhance progress in various aspects of productivity, safe-guarding against any undesirable components of response.

The major question raised by the negative relationships between traits associated with production potential and those with resistance to stress, is whether there are underlying physiological reasons that prevent their combination in a way that will maximise realised productivity. How can high production potential and resistance to stress be combined through selection?

Vercoe & Frisch (1990) suggested that growth of animals could be assessed in two contrasting environments, one of low stress and one of high stress. The growth in the low stress environment would be mainly a reflection of growth potential and in the high stress environment, a reflection of resistance to environmental stresses. Individuals ranked highly in both environments would be those for use in subsequent breeding. One deficiency in such an approach is the unknown effect of compensatory gain and its possible bias towards different animals.

The negative correlations between coat score and body condition score (-0.40) indicated a genetic advantage of a sleek coat in a hot environment. However, sleeker coats were genetically indicative of lower weight gains. Olson *et al.* (2003) found evidence that supports the existence of a major gene (designated as the slick hair gene), dominant in mode of inheritance that is responsible for producing a very short sleek hair coat. Cattle with sleek hair were observed to maintain lower rectal temperatures. The gene is found in Senepol cattle and criollo (Spanish origin) breeds in Central and South America. This gene is also found in a Venezuelan composite breed. A further investigation should be made to determine whether such a slick hair gene is found in the Afrikaner and Drakensberger breeds.

Further, a strong negative correlation (-0.69) was observed between hide thickness and tick count and a positive correlation (0.70) between coat score and tick count, signifying the benefit of a thick hide and sleek coat in a tick infested region.

- **Weight gain**

In the first section of the research where all breeds partook in the study, the Afrikaner gained significantly ($P < 0.001$) less weight than the Bonsmara, Braford, Charolais, Drakensberger and Simmentaler heifers. The Simmentaler heifers had the greatest weight gain of 120.0kg. No significant differences in weight gains were observed between the Bonsmara, Braford and Drakensberger heifers. On the basis of mean weight gain, the breeds have been ranked in order of decreasing weight gain as Simmentaler > Bonsmara, Braford, Charolais, Drakensberger > Afrikaner.

- **Coat colour and breed**

There was not sufficient variation in coat colour within breeds and between certain breeds to assess the relationship of coat colour to heat tolerance (rectal temperatures) as coat colour was a function of breed.

- **Coat score**

Significant ($P < 0.01$) differences in coat scores were observed in each of the five days of observation between breeds. The Afrikaner had the lowest coat score most of the time and the Charolais the highest coat score throughout. Sometimes the Bonsmara, Drakensberger, and the Braford also showed relatively sleek coat scores.

- **Body condition score**

Highly significant ($P < 0.0001$) breed differences in body condition scores were reported throughout the course of the study. The Braford heifers had the highest mean BCS and the Charolais heifers' the lowest mean BCS throughout the duration of the research. The Charolais heifers BCS was significantly lower than that of the Afrikaner, Braford, and Drakensberger heifers. No significant differences in BCS were observed between the Afrikaner and Drakensberger heifers on all three sampling events. On the basis of mean BCS, the breeds have been ranked in order of decreasing BCS as Braford > Afrikaner, Bonsmara, Drakensberger > Simmentaler > Charolais.

- **Hide thickness**

Highly significant ($P < 0.0001$) differences in hide thicknesses were found between breeds. The Afrikaner heifers had the thickest hide throughout course of the research and the Charolais heifers the thinnest hide. No significant differences in hide thicknesses were measured between the Bonsmara, Braford, Drakensberger and Simmentaler heifers. Hide thickness only had a significant influence ($P< 0.05$) on rectal temperature in the Afrikaner and Bonsmara heifers.

- **Tick count**

Across all measurements the Afrikaner heifers had the least ticks and the Charolais heifers the most ticks with the significant difference in tick count between these breeds being $P < 0.001$. No significant differences in tick counts were observed between the Afrikaner and Drakensberger heifers as well as the Braford and Drakensberger heifers. The mean tick counts did not have any significant influence on the rectal temperatures of the heifers. On the basis of mean tick count, the breeds have been ranked in order of decreasing resistance to ticks as Afrikaner, Drakensberger > Braford > Charolais.

- **Respiration Rate (R_r)**

The respiration (R_r) rate between breeds differed significantly only on three days. No breed showed superior values during the trail.

- **Body (rectal) temperature in winter**

No significant differences ($P > 0.1$) in rectal temperatures between breeds were detected on 4 occasions. The Drakensberger heifers had the lowest rectal temperature 5 times while the highest rectal temperature was recorded in the Charolais heifers on the most number of measuring days.

- **Body (rectal) temperature in summer**

Compared to other breeds, the higher RT of the Charolais and Simmentaler heifers was clearly evident and it is assumed that these breeds are not as heat tolerant as the other breeds in the study. The lower rectal temperatures of the Bonsmara, Braford, Drakensberger and especially the Afrikaner are indicative of a superior ability to dissipate heat to maintain a lower rectal temperature.

- **Correlation between hide thickness and tick count**

Hide thickness, which is regarded by Bonsma (1983) as a good indicator of tick resistance was highly negatively correlated (-0.69) to tick count. The significance of this correlation was high ($P < 0.0001$). Prayaga (2003) found that treatment to control ticks and worms resulted in significantly increased live weight gains in a majority of genotypes, highlighting the negative effect of parasite burdens.

- **Correlation between coat score and tick count**

The results of this study contradict results from a study done by Spickett *et al.* (1989) on the resistance of Nguni, Bonsmara and Hereford cattle to ticks in a Bushveld region of South Africa. Spickett *et al.* (1989) could not find any correlation between tick infestations and hair length.

- **Correlation between coat score and body condition score**

A significant ($P < 0.005$) negative correlation between coat score and body condition score across genotypes (-0.40) was found. This negative genetic correlation between coat score and body condition scores indicates a genetic advantage of a sleek coat in a hot environment. Prayaga *et al.* (2009) also found the correlation between coat score and body condition score to be negative (-0.33 to -0.48).

- **Correlation between coat score and weight gain**

A positive correlation (0.33) ($P < 0.01$) between coat score in summer and total weight gain was observed. The *Bos Taurus* breeds had higher coat scores as well as a higher weight gain compared to the other genotypes. The winter coat scores were a better predictor of total weight gain as the correlation between the coat scores in winter and total weight gain was higher (0.48) ($P < 0.0001$) than the correlation between coat score in summer and total weight gain.

5.2 Recommendations

Overall, the Afrikaner exhibited the best performance in the most parameters tested while the Charolais performed worst in most of the parameters. Breeds that also performed well in certain categories are the Drakensberger, Braford and Bonsmara. Despite the Simmentaler's superior weight gain it was susceptible to heat stress as the Charolais. The afore-mentioned breeds may struggle to adapt in the warmer western parts of the country.

It is recommended that farmers farm with the breed most adapted in that area as it may have serious implications on the long term sustainability of farming systems.

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ADDENDUM A

Effect of heat stress on six beef breeds in the Zastron district: the significance of breed, coat colour and coat type

L.A. Foster[1], P.J. Fourie[1], F.W.C. Neser[2] and M.D. Fair[2]
[1]Department of Agriculture, Central University of Technology Free State, Private Bag X20539, Bloemfontein, South Africa.
[2]Department of Animal, Wildlife and Grassland Sciences, University of the Free State, P.O. Box 339, Bloemfontein, South Africa

Abstract

A study was done to determine which factors had the greatest influence on a heifer's susceptibility to heat stress. Parameters tested were breed, coat colour, coat score, hide thickness, weight gain, respiration rate and body condition score. The study was conducted in the southeastern Free State. Afrikaner, Bonsmara, Braford, Charolais, Drakensberger and Simmentaler heifers were submitted to a heat tolerance trial. A total of 60 heifers, 10 of each breed were evaluated. Rectal temperature (T_{re}) was used as a parameter to determine heat stress. The heifers were evaluated on ten days, at 14:00 during the winter of 2007 and on seventeen days, at 14:00 during the summer of 2007/8 (after 1h under the sun, no access to shade). In winter a significant difference ($P < 0.05$) in rectal temperature T_{re} between breeds was measured on seven occasions. Phenotypical factors tested for did not affect T_{re} in winter. In summer significant differences in T_{re} were measured on 12 occasions between breeds. The following factors had significant influence on T_{re} in the following breeds. Afrikaner – hide thickness, Bonsmara – hide thickness, Charolais – coat score.

Keywords: Heat stress, rectal temperature, breed, coat score, coat colour, and hide thickness

Introduction

There is probably no other agricultural sector where there is such an extensive diversity of opinions and perspectives as in the beef industry in South Africa, being it at the level of the farmer or producer or at the level of the animal scientist. These differences are often on the subject of breed, production systems, breeding, supplementation, management, marketing and all sorts of other sentimentality (Mentz, 2002). One of the most significant reasons for these differences in opinions could be that there are hopelessly too many presumptions and philosophies without concrete evidence (Mentz, 2002). A contributing component is that breed standards on which breed improvements are mainly based are not essentially founded on biological values; they are partly synthetic devises wanting scientific basis (Bonsma, 1983).

Keeping livestock that are in harmony with the environment in which they are maintained brings about maximum utilisation of the natural recourses. There is a close correlation between an animal's physiological response (such as body temperatures, respiration rates and pulse rates) and productivity. Temperature is most important in determining which type of animal can be maintained in a particular region (Finch, 1986). The effects of heat on body temperature are determined not only by climate but also by the available food and water. The further an animal moves away from its preferred body temperature, the more harmful temperature becomes to productive processes. Even small upward shifts in core temperature have profound effects on tissues and neuro-endocrine functions, which in turn reduce fertility, growth, lactation, and ability to work (Finch, 1986).

The interaction of genotype and environment (G x E) means simply that the effect of the environment on different genotypes is not the same. This indicates that there is no universally "best" genotype – the "best" genotype will differ from one environment to another and will depend on the prevalent environmental conditions (Verscoe & Frisch, 1990).

To the farmer G x E means using that particular breed of animal that is most productive in its environment. To the scientist it presents the venture of fathoming whether genetic or environmental changes are the most efficient avenues through which productivity can be enhanced. G x E is more consequential in extensive production systems since environmental variables such as nutrition, parasites, disease and climatic conditions cannot be closely controlled (Verscoe & Frisch, 1990).

Stress, in its physical sense, cannot easily be measured in a biological system, but particular exhibitions of stress, such as changes in body temperature, heart rate and respiration can be measured because the animal responds functionally to uphold homeostasis (Du Preez, 2000).

Breed specific adaptation characters may be of utmost importance for proper selection of cattle for specific environments. However any attention to heat tolerance of cattle should include coat colour. Colour is a feature that mediates the impact of solar radiation and affects the extent of heat load on animals. Coat colour can not be examined in isolation; similarly important is the type of coat and its interaction with colour. Structure effects penetration into, and the location of absorption of radiation within the coat (Finch *et al.*, 1984).

The present work is an attempt to describe and evaluate breed, coat colour, coat type and body temperature (rectal temperature) in Afrikaner, Bonsmara, Braford, Charolais, Drakensberger and Simmentaler heifers in an attempt to resolve questions about these breeds adaptability to environmental heat.

Materials and Methods

All experimental procedures were conducted on the farm "Quaggafontein", south of Zastron, in the south-eastern Free State, South Africa. Animals were farmed extensively on the natural pasture occurring in the region. Ten heifers of the Afrikaner, Bonsmara (⅝ Afrikaner, ⅜British), Braford (⅝Hereford, ⅜Brahman), Charolais, Drakensberger and Simmentaler breeds, all between 7 and 9 months of age, were introduced onto the farm during July 2007. Animals were acquired from the same area where the study was conducted to minimise the effect of adaptation. Only animals from stud breeders were selected to ensure the trueness to type of each animal.

Coat colour was divided into eight different colour groups, according to absorption rates. The groups ranged from white (score 0), grey (2), yellow-fawn (4), light-red (6), red (8), dark-red (10), brown (12), dark-brown (14) to black (16). Coat colour was assessed in August 2007 (winter) and again in December 2007 (summer).

The following is a general description of the scoring system used (Turner & Schleger, 1960). Extremely short (score 1), very short (2), fairly short (3), fairly long (4), long (5), woolly (6), very woolly (7). The coat scoring was done once in winter and on four occasions in summer due to breed differences in the shedding process. The Bonsmara and Simmentaler heifers had to be withdrawn from the research in February 2008 due to conflicting breeding programs.

Body condition was appraised according to the scores of thin (1-3), borderline (4), optimum (5-6), and fat (7) and was determined on three occasions from January to March of 2008.

Skin-fold thickness was determined using a caliper. The skin over the midside area was measured as Tulloh (1961) found that the skin over this area is relatively uniform in thickness. Skin-fold thickness was measured in December 2007 and again in January 2008. An additional skin-fold measurement was taken in March 2008 on the Afrikaner, Braford, Charolais and Drakensberger heifers.

Body temperature (rectal temperature) of the same ten heifers of each breed which did experience heat stress during December 2007 and January 2008 (THI > 70, 10-day period) were measured. An additional seven measurements were taken during February 2008 on the Afrikaner, Braford, Charolais and Drakensberger heifers. On days when data was recorded, animals were rounded up and placed in a pen at 13:00. The measuring of rectal temperatures commenced at 14:00 with animals randomly selected.

Respiratory rate (R_r) was counted visually from flank movements in a given time as recorded with a chronometer. Respiratory rate was measured on five individual events in December 2007 and again on six separate occasions in February 2008 on the Afrikaner, Braford, Charolais and Drakensberger. The R_r was determined concurrently with the rectal temperatures.

A Kestrel® 4000 Pocket Weather Tracker was used to measure weather information at 14:00. The best, simplest and most practical parameter for the measurement of environmental warmth, which may cause heat stress in cattle, is the Temperature Humidity Index (THI). The Livestock Weather Safety Index (LWSI) of the Livestock Conservation Institute (1970) was used as a basis for classifying various categories of the THI values. The classification of values is as follows: Normal (70 or less), alert (71 -78), danger (79 -83), emergency (83 and above), (Du Preez, 2000). Data was statistically analysed using analysis of variance in Proc GLM to determine the effect of the different parameters.

Results and Discussion

It was found that coat colour was a function of breed and due to this, the parameter breed rather than coat colour, was used when data was analized.

The results of the study show that highly significant differences in coat scores between breeds were found. The coat scores were affected by season as mean breed coat scores decreased from August through to February. The Afrikaner had the lowest coat score on the 1^{st}, 3^{rd}, 4^{th} and 5^{th} sampling days and the Charolais the highest coat score throughout the course of the study. Bonsma repeatedly stresses the importance of coat type in adaptation (Bonsma, 1983). Turner and Schleger (1960) indicate the potential value of coat characters in selecting tropical beef cattle. However, they conclude that a sleek coat may have a greater significance as an indicator of metabolic efficiency or of a capacity to react favorably to stress.

Table 1 Least-squares breed means (± s.e.) for coat score (CS), 1 being extremely short and 7 very woolly

Parameter	Month	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
CS 1	August	3.6 ± 0.16[a]	4.3 ± 0.15[b]	4.8 ± 0.13[b]	6.4 ± 0.16[c]	4.7 ± 0.15[b]	6.2 ± 0.13[c]
CS 2	December	3.2 ± 0.20[ab]	2.8 ± 0.20[a]	3.0 ± 0.26[a]	4.0 ± 0.21[b]	3.5 ± 0.27[ab]	3.5 ± 0.22[ab]
CS 3	January	1.7 ± 0.15[a]	1.9 ± 0.18[a]	2.7 ± 0.21[bc]	3.6 ± 0.16[d]	2.2 ± 0.13[ab]	3.1 ± 0.10[cd]
CS 4	February	1.3 ± 0.15[a]	-	2.5 ± 0.17[b]	3.4 ± 0.16[c]	1.7 ± 0.15[a]	-
CS 5	March	1.1 ± 0.10[a]	-	2.5 ± 0.17[b]	4.0 ± 0.26[c]	1.8 ± 0.13[d]	-

[1]Means in the same row with different superscript letters differ significantly: P < 0.0001, with the exception of the second day of sampling (CS2) were the significant difference in CS between breeds was P < 0.01.

Highly significant (P < 0.0001) breed differences in body condition score were reported throughout the course of the study. The Braford heifers had the highest mean BCS and the Charolais heifers' the lowest mean BCS throughout the duration of the research. On the basis of mean BCS, the breeds have been ranked in order of decreasing BCS as Braford > Afrikaner, Bonsmara, Drakensberger > Simmentaler > Charolais.

Table 2 Least-squares breed means (± s.e.) for body condition score (BCS), 1 being thin and 9 obese

Parameter	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
BCS 1	6.4 ± 0.16[ab]	6.4 ± 0.16[ab]	6.9 ± 0.10[a]	5.4 ± 0.16[c]	6.2 ± 0.13[b]	5.9 ± 0.10[bc]
BCS 2	7.0 ± 0.00[a]	-	7.0 ± 0.00[a]	5.6 ± 0.16[b]	6.8 ± 0.13[a]	-
BCS 3	7.0 ± 0.00[a]	-	7.9 ± 0.31[b]	5.3 ± 0.15[c]	6.9 ± 0.10[a]	-

[1]Means in the same row with different superscript letters differ significantly: P < 0.0001.

With regards to hide-thickness, highly significant (P < 0.0001) differences were reported between breeds. The Afrikaner heifers had the thickest hide throughout course of the research and the Charolais heifers the thinnest hide. No significant differences in hide thicknesses were noted between the Bonsmara, Braford, Drakensberger and Simmentaler heifers.

The respiration rate was measured on eleven events. The R_r rate between breeds differed significantly (P < 0.01) only on two occasions. On both occasions where a significant differences in R_r was detected the Drakensberger heifers had the lowest respiration rate at an average of 41.6 and 35.6 breaths per minute and the Braford heifers the highest at 54.8, and 63.6 breaths per minute.

Table 3 Least-squares breed means (± s.e.) for hide-thickness (H) measured in millimeters

Parameter	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
H 1	14.1 ± 0.52[a]	12.6 ± 0.60[ab]	12.8 ± 0.51[ab]	8.0 ± 0.30[c]	11.5 ± 0.43[b]	11.4 ± 1.38[b]
H 2	14.6 ± 0.47[a]	12.4 ± 0.52[b]	12.6 ± 0.43[b]	7.9 ± 0.43[c]	11.0 ± 0.49[b]	12.1 ± 0.77[b]
H 3	16.4 ± 0.16[a]	-	14.5 ± 0.54[b]	10.4 ± 0.40[c]	13.4 ± 0.31[b]	-

[1]Means in the same row with different superscript letters differ significantly: P < 0.0001

Highly significant differences (P < 0.01) in rectal temperatures between breeds were measured as illustrated in

Table 4. No significant difference in T_{re} was measured between the Afrikaner, Bonsmara, Braford and Drakensberger heifers as well as between the Charolais and Simmentaler heifers. However the Charolais and Simmentaler heifer's rectal temperatures differed significantly ($P < 0.01$) from that of the rectal temperatures of the Afrikaner, Bonsmara, Braford and Drakensberger heifers.

Table 4 Least squares breed means[1] and (s.e) of rectal temperatures (T_{re}) in summer

Parameter	Afrikaner (*n*=10)	Bonsmara (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)	Simmentaler (*n*=10)
T_{re} 1	39.45 ± 0.18[a]	39.39 ± 0.07[a]	39.50 ± 0.17[a]	39.60 ± 0.06[a]	39.43 ± 0.09[a]	39.40 ± 0.07[a]
T_{re} 2	39.43 ± 0.20[a]	39.34 ± 0.05[a]	39.53 ± 0.21[a]	39.44 ± 0.06[a]	39.37 ± 0.09[a]	39.59 ± 0.15[a]
T_{re} 3	39.26 ± 0.09[a]	39.23 ± 0.04[a]	39.40 ± 0.15[a]	39.56 ± 0.12[a]	39.38 ± 0.17[a]	39.59 ± 0.14[a]
T_{re} 4	39.18 ± 0.08[a]	39.20 ± 0.06[a]	39.38 ± 0.13[ab]	39.74 ± 0.18[b]	39.26 ± 0.04[a]	39.54 ± 0.08[ab]
T_{re} 5	39.22 ± 0.09[a]	39.52 ± 0.14[ab]	39.57 ± 0.19[ab]	39.81 ± 0.04[b]	39.56 ± 0.06[ab]	39.72 ± 0.09[b]
T_{re} 6	38.88 ± 0.14[a]	39.01 ± 0.05[ab]	38.95 ± 0.05[ab]	39.30 ± 0.10[b]	38.95 ± 0.07[ab]	39.26 ± 0.06[b]
T_{re} 7	38.79 ± 0.58[a]	38.93 ± 0.05[ab]	38.85 ± 0.05[a]	39.25 ± 0.04[c]	38.85 ± 0.06[a]	39.11 ± 0.07[bc]
T_{re} 8	38.91 ± 0.04[a]	39.00 ± 0.05[abc]	38.99 ± 0.10[ab]	39.21 ± 0.03[bc]	38.90 ± 0.07[a]	39.26 ± 0.07[c]
T_{re} 9	39.06 ± 0.05[a]	39.07 ± 0.05[a]	38.96 ± 0.06[a]	39.37 ± 0.05[b]	39.13 ± 0.06[ab]	39.36 ± 0.08[b]
T_{re} 10	39.31 ± 0.08[ab]	39.51 ± 0.15[ab]	39.17 ± 0.06[a]	39.74 ± 0.13[b]	39.34 ± 0.11[ab]	39.56 ± 0.07[ab]
T_{re} 11	39.18 ± 0.09[a]	-	39.16 ± 0.07[a]	39.47 ± 0.04[b]	39.20 ± 0.03[a]	-
T_{re} 12	39.03 ± 0.05[a]	-	38.97 ± 0.05[a]	39.41 ± 0.05[b]	39.04 ± 0.05[a]	-
T_{re} 13	39.08 ± 0.04[a]	-	39.09 ± 0.07[a]	39.56 ± 0.06[b]	39.09 ± 0.04[a]	-
T_{re} 14	39.11 ± 0.06[a]	-	39.05 ± 0.07[a]	39.72 ± 0.08[b]	38.98 ± 0.05[a]	-
T_{re} 15	39.11 ± 0.05[a]	-	38.95 ± 0.06[a]	39.55 ± 0.06[b]	39.04 ± 0.07[a]	-
T_{re} 16	38.96 ± 0.13[a]	-	39.35 ± 0.23[a]	39.60 ± 0.25[a]	39.03 ± 0.10[a]	-
T_{re} 17	39.00 ± 0.10[ab]	-	38.83 ± 0.06[a]	39.21 ± 0.05[b]	38.97 ± 0.15[ab]	-

[1]Means in the same row with different superscript letters differ significantly: $P < 0.01$

Conclusions

From the results in this study it is clear that breed is the only parameter measured affecting rectal temperature and thus heat tolerance in all the animals. The following factors had a significant influence ($P < 0.05$) on the rectal temperatures in the following breeds: Afrikaner – hide thickness, Bonsmara – hide thickness, Charolais – coat score. It would appear that the Charolais and Simmentaler heifers would be more prone to suffer from heat stress as these breeds had elevated rectal temperatures compared to the other breeds on hot days.

Acknowledgements

The author would like to thank the NRF for financial support.

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Differences in physical traits such as coat score and hide-thickness together with tick burdens and body condition score in four breeds in the Southern Free State

L.A. Foster[1], P.J. Fourie[1], F.W.C. Neser[2] and M.D. Fair[2]

[1]Department of Agriculture, Central University of Technology Free State, Private Bag X20539, Bloemfontein, South Africa.
[2]Department of Animal, Wildlife and Grassland Sciences, University of the Free State, P.O. Box 339, Bloemfontein, South Africa

Abstract

A study was conducted to determine differences between four breeds pertaining to coat score, hide-thickness, tick burden and body condition score. Forty heifers representing four breeds (10 from each breed) were used. The participating breeds were Afrikaner, Braford, Charolais and Drakensberger. A system of subjective scoring of cattle coats, ranging from extremely short to very woolly was used. Body condition score was measured subjectively with 1 being emaciated and 9 being obese. Hide-thickness (in mm) and tick counts were also determined. Measurements were carried out on the same ten animals of each breed from August 2007 to early March 2008. Highly significant ($P < 0.0001$) differences in body condition score, hide-thickness and tick counts were observed between breeds on all instances. Coat scores differed significantly ($P < 0.0001$) between breeds in the earlier and latter stages of the study becoming less significant midway in the study. There was also a significant ($P < 0.0001$) difference in body condition score within breeds. Hide-thickness did not differ significantly within breeds.

Keywords: Coat score, hide-thickness, tick burden, body condition score

Introduction

Farmers are constantly looking for ways to improve production and profitability of their livestock enterprises. Choosing a cattle breed to farm is one of the most important decisions a farmer will have to make.

Cattle have to be productive in an environment that can be described in terms associated with heat, ultraviolet radiation, humidity, parasites, diseases and nutrition. Susceptibility to these stressors accounts for large differences in growth rate, fertility and mortalities between and within breeds. It stands to reason that stress-resistant breeds are more profitable. In the case of parasite control, parasiticides are expensive and the development of resistant strains of parasites confines the options for control and amplifies expenses further (Maree & Casey, 1993). While evaluating the resistance of beef cattle breeds of African, European, and Indian origins to ticks Frisch & O'Neill (1998) found that even while low tick infestations were reported during their research, the regression of live-weight gains on tick counts was about 0.5 kg per tick per year for each genotype.

The main force responsible for selection in nature is the survival of the fittest in a particular environment. Nature tends to select against the weaker animals and only the strong survive to reproduce the species. In the long run natural selection leads to an improved genetic acclimatisation to the prevailing environmental interactions (Du Preez, 2000). Adaptability plays a vital role in trouble-free commercial cattle farming. There is no doubt that the adaptability marvel exhibited by animals in unfavourable climates has a parallel in our domestic animals. Consequently, by applying our knowledge of the occurrence of adaptability, we can breed for adaptability in our domestic livestock without having to suffer losses, which a process of natural selection would have caused (Bonsma, 1983).

The present work is an attempt to describe and evaluate breed, coat type, body condition score, hide thickness and their relevance to tick burdens in Afrikaner, Braford, Charolais and Drakensberger.

Materials and Methods

All experimental procedures were conducted on the farm "Quaggafontein", south of Zastron, in the south-eastern Free State, South Africa. Animals were farmed extensively on the natural pasture occurring in the region. Ten heifers of the Afrikaner, Braford (⅝ Hereford, ⅜ Brahman), Charolais and Drakensberger breeds, all between 7 and 9 months of age, were introduced onto the farm during July 2007. Animals were acquired from the same area where the study was conducted to minimise the effect of adaptation. Only animals from stud breeders were selected to ensure the trueness to type of each animal.

The following is a general description of the scoring system used (Turner & Schleger, 1960). Extremely short (score 1), very short (2), fairly short (3), fairly long (4), long (5), woolly (6), very woolly (7). The coat scoring was done once in winter and on four occasions in summer due to breed differences in the shedding process. The Bonsmara and Simmentaler heifers had to be withdrawn from the research in February 2008 due to conflicting breeding programs.

Body condition was appraised according to the scores of thin (1-3), borderline (4), optimum (5-6), and fat (7) and was determined on three occasions from January to March of 2008.

Skin-fold thickness was determined using a caliper. The skin over the midside area was measured as Tulloh (1961) found that the skin over this area is relatively uniform in thickness. Skin-fold thickness was measured in December 2007 and again in January 2008. An additional skin-fold measurement was taken in March 2008 on the Afrikaner, Braford, Charolais and Drakensberger heifers.

Animals in the experimental group were allowed to become naturally infested with ticks without acaricidal intervention except for patch treatments applied in October and November to contain *Boophilus decoloratus*, *Hyalomma marginatum rufipes* and *Rhipicephalus evertsi* infestations. Two officers, one on either side, carefully examined the restrained animals, recording all visible ticks. The species of tick were not specified and ticks were not removed from the animal. Tick burdens were determined on five events during February 2008.

Results and Discussion

Highly significant ($P < 0.0001$) differences in coat scores were observed in each of the five sampling events between breeds except on the second sampling were the significant difference between breeds concerning coat score was slightly lower ($P < 0.05$). The Afrikaner had the lowest coat score on the 1st, 3rd, 4th and 5th sampling days and the Charolais the highest coat score throughout the course of the study. It is clear that the coat scores were affected by season as mean breed coat score decreased from August through to February. Peters *et al.* (1982) report likewise results finding breed differences in coat type to be highly significant ($P < 0.001$). Turner and Schleger (1960) established that coat score was effected by season, age, sex, pregnancy and lactation, nutrition, breed and individual differences but that the greatest contribution to the differences in coat score being breed. Bonsma (1983) repeatedly stresses the importance of coat type in adaptation and presents striking examples of it. Turner and Schleger (1960) indicate the potential value of coat characters in selecting tropical beef cattle. However, they conclude that a sleek coat may have a greater significance as an indicator of metabolic efficiency or of a capacity to react favourably to stress.

Table 1 Least-squares breed means (± s.e.) for coat score (CS), 1 being extremely short and 7 very woolly

Para-meter	Month	Afrikaner (n=10)	Braford (n=10)	Charolais (n=10)	Drakensberger (n=10)
CS 1	August	3.6 ± 0.16^{a}	4.8 ± 0.13^{b}	6.4 ± 0.16^{c}	4.7 ± 0.15^{b}
CS 2	December	3.2 ± 0.20^{ab}	3.0 ± 0.26^{a}	4.0 ± 0.21^{b}	3.5 ± 0.27^{ab}
CS 3	January	1.7 ± 0.15^{a}	2.7 ± 0.21^{bc}	3.6 ± 0.16^{d}	2.2 ± 0.13^{ab}
CS 4	February	1.3 ± 0.15^{a}	2.5 ± 0.17^{b}	3.4 ± 0.16^{c}	1.7 ± 0.15^{a}
CS 5	March	1.1 ± 0.10^{a}	2.5 ± 0.17^{b}	4.0 ± 0.26^{c}	1.8 ± 0.13^{d}

[1]Means in the same row with different superscript letters differ significantly: P < 0.0001, with the exception of the second day of sampling (CS2) were the significant difference in CS between breeds was P < 0.05.

Body condition score is an effective tool for cattle producers who cannot weigh cattle and it may even surpass the measurement of cow weight in improving reproductive performance. Most studies show that body condition decreases at a faster rate than weight loss (Rossi and Wilson, 2006). Highly significant (P < 0.0001) breed differences with regards to body condition score were reported throughout the course of the study. There was also a significant (P < 0.0001) difference in body condition score within breeds. On the basis of mean BCS, the breeds have been ranked in order of decreasing BCS as Braford > Afrikaner, Drakensberger > Charolais.

Table 2 Least-squares breed means (± s.e.) for body condition score (BCS), 1 being thin and 9 obese

Para-meter	Month	Afrikaner (n=10)	Braford (n=10)	Charolais (n=10)	Drakensberger (n=10)
BCS 1	January	6.4 ± 0.16^{ab}	6.9 ± 0.10^{a}	5.4 ± 0.16^{c}	6.2 ± 0.13^{b}
BCS 2	February	7.0 ± 0.00^{a}	7.0 ± 0.00^{a}	5.6 ± 0.16^{b}	6.8 ± 0.13^{a}
BCS 3	March	7.0 ± 0.00^{a}	7.9 ± 0.31^{b}	5.3 ± 0.15^{c}	6.9 ± 0.10^{a}

[1]Means in the same row with different superscript letters differ significantly: P < 0.0001.

The animal hide, consisting of the skin and hair covering, is the largest organ of the body. The skin comprises approximately seven to eight percent of the live weight of the animal. The hide is of paramount importance in determining the adaptability of the animal to prevailing environmental conditions as it forms a barrier between the external environment and the animal (Bonsma, 1983). A highly significant (P < 0.0001) difference in hide thickness between breeds was reported. The Afrikaner heifers had the thickest hide throughout course of the study and the Charolais heifers the thinnest hide. No significant differences in hide-thickness were noted between the Braford and Drakensberger heifers. These results contradict research done by Spickett *et al*. (1989) who found no significant difference in double skin-thickness between Nguni, Bonsmara and Hereford breeds and thus no correlation between skin thickness and tick resistance could be determined.

Table 3 Least-squares breed means (± s.e.) for hide-thickness (H) measured in millimeters

Para-meter	Month	Afrikaner (n=10)	Braford (n=10)	Charolais (n=10)	Drakensberger (n=10)
H 1	December	14.1 ± 0.52^{a}	12.8 ± 0.51^{ab}	8.0 ± 0.30^{c}	11.5 ± 0.43^{b}
H 2	January	14.6 ± 0.47^{a}	12.6 ± 0.43^{b}	7.9 ± 0.43^{c}	11.0 ± 0.49^{b}
H 3	March	16.4 ± 0.16^{a}	14.5 ± 0.54^{b}	10.4 ± 0.40^{c}	13.4 ± 0.31^{b}

[1]Means in the same row with different superscript letters differ significantly: P < 0.0001

Across all measurements the Afrikaner heifers had the least ticks and the Charolais heifers the most ticks with the significant difference in tick count between these breeds being $P < 0.001$. No significant differences in tick counts were observed between the Afrikaner and Drakensberger heifers. In the present study, the indigenous Afrikaner and Drakensberger breeds had a lower tick infestation compared to the Braford and Charolais heifers. Spicket *et al*. (1989) showed likewise results in that the indigenous Nguni breed harboured significantly fewer ticks during periods of peak abundance than either Bonsmara or Hereford cattle. Frisch and O'Neill (1998) ranked the Charolais sire breed last for tick resistance thus also corroborating present research. On the basis of mean tick count, the breeds have been ranked in order of decreasing resistance to ticks as Afrikaner, Drakensberger > Braford > Charolais.

Table 4 Least-squares breed means (± s.e.) for tick (T) counts

Parameter	Date	Afrikaner (*n*=10)	Braford (*n*=10)	Charolais (*n*=10)	Drakensberger (*n*=10)
T 1	06-02-2008	12.3 ± 1.71[a]	20.2 ± 2.70[a]	36.2 ± 2.58[b]	18.2 ± 1.74[a]
T 2	13-02-2008	9.0 ± 1.04[a]	14.9 ± 2.64[a]	24.7 ± 3.00[b]	14.1 ± 1.72[a]
T 3	20-02-2008	9.6 ± 0.83[a]	15.9 ± 1.35[ab]	21.9 ± 2.34[b]	14.0 ± 1.77[a]
T 4	27-02-2008	13.4 ± 1.43[a]	21.6 ± 1.78[bc]	27.1 ± 2.90[c]	17.2 ± 2.15[ab]
T 5	05-03-2008	15.1 ± 1.48[a]	21.7 ± 2.21[ab]	26.2 ± 1.57[b]	17.7 ± 1.83[a]

[1]Means in the same row with different superscript letters differ significantly: $P < 0.001$

Conclusion

From this study it is evident that breeds differ in their capacity to resist ticks. The indigenous Afrikaner and Drakensberger breeds as well as the Braford heifers to some extent, appear to surpass the Charolais heifers in their ability to resist ticks. These animals had significantly thicker hides as well as sleeker coats, which act as a deterrent to ticks, resulting in lower tick infestations.

Acknowledgements

The author would like to thank the NRF for financial support.

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