

Investigation of tick infestation on udders of beef cows and the related effects on calf survival and growth to weaning in the Mnisi tribal community.

By

Nomusa Kgomotso Jaca

Thesis presented in fulfillment of the requirements for the degree of Masters in Animal Production and Management (Animal Sciences) in the Faculty of Natural and Agricultural Sciences at Pretoria University

Supervisor: Prof. Edward C. Webb
Co-supervisor: Prof. Darryn Knobel

November 2017

Declaration

By submitting this thesis/dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Pretoria University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Abstract

Ticks are important ectoparasites and vectors of human and animal diseases in many countries including South Africa (Matayo, 2001). In Matabeleland, south province, some recent work has been done by VEDMA consulting group (2005) and confirmed that tick infestation and tick borne diseases (TBD) are some of the most important conditions affecting livestock productivity (Ndhlovu, 2008). Ticks are responsible for direct damage to livestock skins and hides because of their feeding habits, damaging udders, teats, scrotum and other exposed animal parts due to infestation of damaged sites by maggots and secondary microbial infections (Norval 1983, Meltzer and Norval 1993; Dreyer, Fourie and Kok, 1998). Productivity losses which can occur (Norval et al., 1988; 1989; Stachurski et al., 1993; Meltzer et al., 1995; Jonsson, 2006) may not be obvious to communal small-scale farmers. Heavy infestations can cause loss of blood, reduce the rate of live-weight gain and lower milk yield, whilst the long mouthed ticks downgrade the quality of the hides (De Castro, 1997).

The objective of the study was to investigate tick infestation and distribution on cow udders, evaluating the level of udder damage caused by ticks and the impact this has on growth of calves until weaning age and survival rate. In coming up with a strategy to improve the calf survival to weaning age and reducing tick infestation rate on cow udders in extensive cattle production systems, an understanding of manipulation of factors which contribute to tick attachment, milk availability for calf suckling and calf growth and development to weaning age are to be considered. Not many farmers practice regular tick control strategies because of ignorance, negligence and poverty (Davidi, 2001). The South African government has strategically and traditionally provided the means and infrastructure for tick control in communal farming areas (Stevens et al., 2007) as an incentive for farmers to present their animals for weekly inspection and disease control interventions. Control of ticks and tick-borne diseases (TBDs) in small-scale sectors has been one of the major initiatives implemented by the Mpumalanga Veterinary Services (MVS). Despite their well-known disadvantages, resistance, environmental pollution, residues in meat, milk, hides and skins and natural toxicity, acaricides are the backbone of tick control as they are effective both in the short-term by cleaning the animal of ticks and in the long-term in reducing tick burdens.

The prevalence of tick attachment on dam udders was investigated, investigating the level of tick attachment (TAS) and level of udder damage (CUS) to lactating cows. This in turn allowed for further evaluation of the impact TAS and CUS scores had on calf growth to weaning (ADG). The degree of tick infestation on dams showed a tendency towards having a significant relationship to the dam's body condition score ($P=0.1$), and the udder score of lactating dams is associated with the dip-tank the dam dips at on a regular basis. The dip-tank the calf and dam

are associated with has an influence to growth and development of calf (ADG), ($P < 0.05$). Calf time to death was evaluated against calf associated independent variables, showing no significant association to calf time of death, $P > 0.05$.

Keywords: Tick infestation, udder damage, calf growth, calf survival, weaning, body condition score (BSC), cow udder score (CUS)

Acknowledgement

I would like to thank the University of Pretoria Bursary for funding this project. I am grateful to my supervisors Professor Edward C. Webb and Professor Darryn Knobel for all their hard work and support throughout this Masters. I would also like to thank Mr Roelf Coertze and Dr Anne Conan for assisting me with the statistical analyses. I extend my gratitude to Mr Vincent Khoza of the University of Pretoria Environmental Monitors who worked with me every day in collecting data in the villages, thank you to the Hluvukani Animal Clinic team.. Thank you to the Mpumalanga Veterinary Public Health team for their warm welcome, support and assistance; Dr Bjorn Reininghaus (State Vet) and Mr Jerry Ndlozi (Animal Health Technician). Many thanks go to the Mnisi community and the villages of Clare A, Clare B , Welverdiend A, Welverdiend B and Thlavekisa who made this project possible through their participation during data collection. My most humblest of gratitude to the Hans Hoheisen Wildlife Research Station team for their warm welcome and providing accommodation for me throughout the data collection period. To my mother, father, brother and his family, thank you for being my strong pillars and source of comfort during this journey. To my aunt, Isa Lindstroom, thank you for always encouraging me and reminding me to 'vasbyt'. To the rest of my family and friends, I would like to thank you all for praying for me and supporting me throughout my studies. Above all, I thank God for keeping me and taking me through from the beginning to the end of this journey.

Psalm 9:1

I will give thanks to you, Lord, with all my heart; I will tell of all your wonderful deeds.
Amen.

Table of Contents

Declaration.....	i
Abstract.....	ii
Acknowledgement.....	iv
Table of contents.....	v
List of Tables.....	ix
List of Figures.....	x
INTRODUCTION.....	1
1.1. Project Theme.....	1
1.2. Project Title.....	1
1.3. Motivation.....	1
1.4. Purpose of Study.....	3
1.5. Sudy Objective.....	4
1.5.1. Cross-sectional Study (Objective 1).....	4
1.5.2. Cohort Study (Objectives 2 & 3).....	4
1.6. HYPOTHESIS.....	4
2. LITERATURE REVIEW.....	6
2.1. Background.....	6
2.2. Udder Physiology.....	6
2.3. The Cow’s Mammary Gland Defense Mechanism.....	7
2.4. Methods Used to Analyze Udder Health.....	7
2.5. Ticks, Tick Physiology, Attachment and Feeding, Tick Control.....	8
2.6. Tick Resistance.....	9
2.7. Acaricides.....	9
2.8. Immunisation Against Ticks.....	10
2.9. Genetic resistance.....	10
2.10. Tick Reproduction.....	11
2.11. Diseases Associated with Ticks.....	11
2.11.1. Pseudocowpox.....	12
2.11.2. Herpes Mammillitis.....	12
2.11.3. Papilloma.....	13

2.11.4. Cowpox	13
2.11.5. Foot and Mouth Disease (FMD)	13
2.11.6. Vesicular Stomatitis	13
2.12. Fungi.....	13
2.12.1. Ringworm.....	13
2.12.2. Bacteria	14
2.13. Abundant Tick Species Found in Mpumalanga cattle.....	15
2.13.1. Amblyomma hebraeum	15
2.13.2. Rhipicephals (boophilus) microplus.....	15
2.14. Influence of Heifer’s and/or Dam’s Nutritional Requirements on Calves Growth and Development.....	15
2.15. Defense Mechanisms for Calve Survival	16
2.15.1. Colostrum as first defense	16
2.15.2. Rumen development of young calf.....	17
2.16. Nutritional Needs for Calf Growth and Development	18
2.17. Genetic Influences on the Calf’s Growth and Development	18
2.18. Calf Environmental Management at Weaning	19
3. MATERIALS AND METHODS	21
3.1. Study area	21
3.2. Dip tank layout.....	21
3.3. Study design.....	23
3.3.1. Cross sectional study.....	23
3.3.1.1. Udder palpation procedures.....	23
3.3.1.2. Udder symmetry	24
3.3.1.3. Cow udder score (CUS)	24
3.3.1.4. Tick attachment scoring criteria	25
3.4.5. Body condition score	25
3.4. Cohort study.....	25
3.4.1. Dam breed-types	26
3.4.2. Dam age category	26
3.4.3. Dam body condition score (BCS).....	26
3.4.4. Dam heart girth (HG)	26

3.4.5. Enrolment of calves	26
3.4.6. Follow-up calves.....	27
3.5 Data Analysis.....	27
3.5.1. Description of variables	27
3.5.2. Evaluation of the relationship of dam and calf factors on calf average daily gain (ADG)	28
3.5.3. Factors associated with dam CUS and TAC.....	28
3.5.4. Survival analyses	29
3.6. Ethics statement	29
4 RESULTS.....	30
4.1. Cross Sectional Study Results.....	30
4.2. Cohort Study Results.....	35
4.2.1 Description of study population	35
4.2.2 Description of dam population	35
4.2.3. Description of calf population.....	38
4.3. ANALYSES	39
4.3.1. Association of CUS and TAS with ADG (Linear regression)	39
4.3.2. Factors associated with dam CUS and TAS (ordinal regression).....	40
4.3.3. Factors associated with calf average daily gain, (linear regression).....	42
4.3.4. Factors associated with calf survival.....	47
4.3.4.1. Association of CUS and TAS with calf survival (survival analysis)	47
5. DISCUSSION.....	49
5.1. Cross Sectional Study	49
5.1.2. Cow udder examination results	49
5.1.3. Relationship between cow udder score (CUS) and tick attachment score (TAS)	49
5.1.4. Relationship between cow body condition score (BCS) and cow udder score (CUS).....	49
5.2. Cohort Study	50
5.2.1 Description of study population	50
5.2.2. Description of dam population	51
5.2.2.1. Dam age	51
5.2.2.2. Dam parity.....	51
5.2.2.3. Dam udder tick infestation and CUS.....	52
5.2.3. Description of calf population.....	52

5.3. ANALYSES	54
5.3.1. Association of CUS and TAC with ADG (Linear regression).....	54
5.3.1.1. Tick attachment on dam udders and calf ADG	54
5.3.1.2. Dam CUS and calf ADG.....	54
5.3.2. Factors associated with dam CUS and TAC (ordinal regression)	55
5.3.2.1. Influence of Dam factors on TAC	55
5.3.2.2. Influence of Dam factors on CUS	55
5.3.3. Factors associated with calf ADG (linear regression).....	56
5.3.3.1. Dip tank influence on calve ADG.....	56
5.3.3.2. Dam age category and the influence it has on calve ADG	57
5.3.3.3. Influence of calf initial weight on calf ADG.....	57
5.3.3.4. Relationship of calf birth month and weaning month on calf ADG	58
5.3.4. Factors associated with calf survival.....	58
6. CONCLUSION.....	59
6.1. Dam factors.....	59
6.2. Calf factors	59
6.3. Recommendations	59
7. LIST OF APPENDICES	61
7.1 Dam Evaluation Sheet.....	61
7.2 Dam Udder Damage Evaluation Sheet.....	62
7.3 Calf Evaluation Sheet	63
8.REFERENCES.....	64

List of Tables

Table 4.1: Frequency distribution of different udder (teat and quarter) damage of cows evaluated at ward B2 dip-tanks in the Mnisi community.....	30
Table 4.2 Frequency distribution showing level of tick attachment on udders (TAS) and cow udder score (CUS) on cows evaluated at ward B2 dip-tanks in the Mnisi community.....	33
Table 4.3 Frequency distribution of body condition scores (BCS) and cow udder scores (CUS) of cows evaluated at dip-tanks in the Mnisi community.....	34
Table 4.4 Frequency distribution of dam breeds per dip-tank.....	35
Table 4.5 Frequency distribution of cow age category at different dip-tanks in sample of 157 studied dams (Age category 1: ≤ 4years of age; Age category 2: > 4 years of age).....	35
Table 4.6 Frequency distribution of cow parity at different dip-tanks in sample of 157 studied dams.....	36
Table 4.7 Tick attachment scores (TAS) and distribution of dams assessed at different dip-tanks in the Mnisi community.....	36
Table 4.8 Cow udder scores (CUS) and distribution of dams assessed at different dip-tanks in the Mnisi community.....	36
Table 4.9 Representation of calves according to breed-type and sex.....	37
Table 4.10 Univariate Linear regression of ADG.....	39
Table 4.11 Ordinal regression table showing the association between dam factors and tick attachment scores (TAS).....	40
Table 4.12 Ordinal regression table showing association between dam factors and cow udder scores (CUS).....	41
Table 4.13 Univariate linear regression results for dam variables and their association with average daily gain (ADG) of calves.....	42
Table 4.14 Univariate linear regression results for calf variables and their association with calf ADG.....	46
Table 4.15 Table representing relationship in calf survival with dependent variables.....	47

List of Figures

Figure 3.1 Map of Ward B1 dip tanks, bordered by the Manyeleti and Timbavati game reserve fence. The black line represents the fence of the reserves Google Earth maps, Map.....	21
Figure 3.2 Dam udder inspections and evaluations.....	23
Figure 3.3 Weighing of calf using the block and tackle system and salter gauge scale.....	26
Figure 4.1 Distribution of number of cows with different types of damage to the udder.....	31
Figure 4.2 Distribution of total scores for CUS score ranking obtained for each cow when all the palpation scores were summed.....	32
Figure 4.3 Distribution of enrolled calves in study.....	38
Figure 4.4 Survival curve for calves enrolled with two weeks of birth (n = 157).....	38
Figure 4.5 Average daily gains of calves from dams with different tick infestation levels udders.....	44
Figure 4.6 Distribution of calf ADG at different CUS scores.....	44
Figure 4.7 Distribution of calf ADG at different dip-tanks.....	45
Figure 5.1 Causal diagram for regression model showing variables influences on calve ADG and survival rate.....	49

INTRODUCTION

1.1. PROJECT THEME

Animal production focusing on cattle infested with ticks and the influence this has on calf growth and development to weaning.

1.2. PROJECT TITLE

Investigation of tick infestation on udders of beef cows and the related effects on calf survival and growth to weaning in the Mnisi tribal community.

1.3. MOTIVATION

Beef cattle production plays an important role in the South African agricultural sector (Rafael Jose Airone Escrivao, 2012), contributing 40% of the agricultural GDP, 15% of the Total Food Energy globally and 25% of the dietary protein globally. (DAFF, 2005; 2010). Extensive beef cattle farming provides farmers with an efficient means of utilizing forages grown from pasture, rangelands and crop residues, which are converted into animal protein. Extensive beef cattle farming not only provide meat but also contribute to household livelihoods through milk, ploughing, transport and social standing (Rafael Jose Airone Escrivao, 2012). According to the Food and Agriculture Organization of the United Nation (FAO), 640 million smallholders and 190 million pastoralists are raising livestock. They make up 70% of the world's poor (FAO 2005. FAOSTAT database. Rome, Italy). Developing the livestock sector therefore has a large potential to reduce poverty (Gura, 2008).

In South Africa the amount of beef produced depends on the country's infrastructure, which is highly developed for transportation of cattle and calves from one area to the other and to other countries such as Namibia. Mpumalanga commands the greatest share of beef produced in South Africa accounting for 23% of the beef produced in South Africa (DAFF, 2010). The province also has the highest cattle slaughter numbers, at 574 808 cattle slaughtered between Novemembr 2016 and October 2017 (RMLA,2017).

There is a need to improve efficiency of livestock production in South Africa (Visagie & Pieter,; 2012). It has been suggested that beef cow efficiency can be improved by tailoring cow size to the environment and improving the adaptive stability (Bonsma,1983; Kalting et al., 1993). This suggestion is due to the important influence that cow size has on the way that the cow responds to the environmental stressors (Arango & van Fleck, 2002) and her ability to adapt to the environment thus being able to tolerate adverse environmental conditions and be able to maintain reproductive efficiency (Prayaga & Henshall, 2005). The efficiency of a beef cattle

production system depends on the reproductive rate of the cows, the growth rate of the calf to weaning and the overall efficiency of feed utilization (Duarte- Ortuno et al., 1988; Pieris et al., 1995; Naazie et al., 1999; Morrison et al., 1999; Kanuya et al., 2006; Nqeno et al., 2010). Qualitative and quantitative aspects of animal nutrition influence the reproduction, growth, and efficiency of beef production systems (Rafael Jose Airone Escrivao, 2012).

Since reproduction is a major component of production efficiency in a beef cattle production system, numerous studies have been performed to understand the factors that influence reproduction in post-partum beef cows (Rafael Jose Airone Escrivao, 2012). Body condition score (BCS) has been reported to be a good indicator of body energy reserves and re-breeding performance (Houghton et al., 1990; Morrison et al., 1999; Ayres et al., 2009). It has been found that cows with greater BCS at parturition return early to oestrus and experience high conception rates (Laflamme & Connor, 1992; Osoro & Wright, 1992; DeRouen et al., 1994). However BCS has a negative correlation with body weight (BW) (Ayres et al., 2009) which indicates that the energy balance is probably a better predictor of reproduction in the post-partum period.

Ticks are important ectoparasites and vectors of human and animal diseases in many countries including South Africa (Matayo, 2001). In Matabeleland, south province of Zimbabwe, some recent work has been done by VEDMA consulting group (2005) and confirmed that tick infestation and tick borne diseases (TBD) are some of the most important conditions affecting livestock productivity (Ndhlovu, 2008). Tick attachment on livestock is responsible for direct damage to the livestock skins and hides. This is due to the ticks' feeding habits, resulting in damaging udders, teats, scrotum and other exposed animal parts due to infestation of damaged sites by maggots and secondary microbial infections (Norval 1983, Meltzer & Norval 1993; Dreyer, Fourie and Kok, 1998). Productivity losses which can occur (Norval et al., 1988, 1989; Stachurski et al., 1993; Meltzer et al., 1995; Jonsson, 2006) may not be obvious to communal small-scale farmers but are important if raising of cattle is to be done at a commercial level.

Because of their direct and indirect effects on their hosts, ticks are considered to not only be a serious threat to successful livestock production but also interfere with the economy of the country, especially in Africa (Mekonnen, 2002). Heavy infestations can cause loss of blood, reduce the rate of live-weight gain and lower milk yield, whilst the long mouthed ticks downgrade the quality of the hides (De Castro, 1997). It is estimated that 80% of the world's 1214 million cattle suffer to some extent from deleterious effects caused by ticks (McCosker, 1979).

Despite the heavy tick infestation of domestic animals, few farmers practice regular control strategies because of ignorance, negligence and poverty (Davidi, 2001). As an incentive for

farmers to present their animals for weekly inspection and disease control interventions, the South African government has strategically and traditionally provided the means and infrastructure for tick control in communal farming areas (Stevens et al., 2007) Control of ticks and tick-borne diseases (TBDs) in small-scale sectors has been one of the major initiatives implemented by the Mpumalanga Veterinary Services (MVS). But because of challenges such as water access and availability in villages, the MVS has been challenged with constraints which affected the dipping services provided by them at dip-tanks. This has had an effect on the tick dynamics in the affected areas (Ndhlovu, 2009).

The objective of the study was to examine tick infestation and distribution on cow udders, evaluating the level of udder damage caused by ticks and the impact this has on growth of calves until weaning age. Results from the study will add to existing knowledge, laying a foundation for further research to be done on ticks, TBDs and calf survival and production in communal livestock farming areas in southern Africa.

1.4. PURPOSE OF STUDY

In coming up with a strategy to improve the calf survival to weaning age and reducing the tick infestation rate on cow udders in extensive cattle production systems, firstly an understanding of the complex manipulation of factors which contribute to tick attachment, milk availability for calf suckling and calf growth and development to weaning age are to be considered. However very few studies concerning this have been conducted with climate and breed type varying significantly. There have been studies done on tick infestations in cattle herds, investigating different tick species, their distribution and the impact the ticks have on cattle with special emphasis on udder and teat damage at selected dip-tanks and farms of Matabeleland South Province, Zimbabwe.(Ndhlovu et al., 2009). Tick-infested udders are prone to damage, predisposed to mastitis and abscessation (Meltzer & Norval 1993; Dreyer *et al.*, 1998; Dreyer *et al.*, 1998; Tibary & Anouassi 2000; Ndhlovu et al., 2009).

The purpose of this study is to help the researchers and farmers understand the effect of udders infested with ticks, the level of udder damage caused by the ticks and the effect it has on calf growth and survival rate, with the aim of developing better, more efficient and effective management practices and techniques to lower tick attachments on dam udders. The study evaluates the extent of damage done on the udders and how this affects the production efficiency of the calves to weaning age. From the study we will add to existing knowledge, guide animal health managers and lay a foundation for further research on tick infested udders and the influence this has on the suckling calf's productivity to weaning age and older.

1.5. STUDY OBJECTIVES

The objectives of the study were to (1) assess the prevalence of udder damage in cows, (2) assess the effect of dam udder damage on calf growth, (3) assess the effect of dam factors on calf growth to weaning at 7 months, and (4) assess the effect of dam udder condition on calf survival to weaning age.

The study was designed in two parts:

1.5.1. Cross-sectional study (Objective 1)

1. Survey of udder damage in cows
2. Development of a scoring system for udder and teat damage

1.5.2. Cohort study (Objectives 2 & 3)

1. Survey and evaluation of dam udder damage using scoring system developed in cross-sectional study
2. Measure the birth weights of calves
3. Monthly body weight measurement of calves to weaning (1-7 months)
4. Survival rate of calves to weaning
5. Evaluate effect of dam udder damage on calf weight at weaning and survival to weaning

1.6. HYPOTHESIS

The study hypothesized that the subsistence cattle farmers of Mnisi Community, ward B1 are challenged by tick infestation on their cattle therefore causing poor calf growth and development to weaning age. To validate this claim the following hypotheses were tested in attempt to address the research problem. A 95% confidence interval was used ($\alpha = 0.05$).

1. Null hypothesis₁ (H_{01}): (a) Calf growth and development to weaning age is independent of level of tick infestation on dam udders, (b) Calf growth and development to weaning age is independent of dam's udder score
2. Null hypothesis₂ (H_{02}): (a) Dam's tick infestation level and udder score is independent of dip-tank influences, (b) Dam's tick infestation level and udder score is independent of dam age- category and parity influences, (c) Dam's tick infestation and udder score is independent of dam BCS influences, (d) Dam's tick infestation and udder score is independent of heart girth influences, (e) Dam's tick infestation and udder score is independent of breed-type influences.
3. Null hypothesis₃ (H_{03}): (a) Calf growth and development to weaning age is independent of calf's birth weight, (b) Calf growth and development to weaning age is independent of calf birth and weaning month, (c) Calf's growth and development to weaning age is

independent of dip-tank, (d) Calf's growth and development to weaning age is independent of calf's sex.

4. Null hypothesis₃ (H_{04}): (a) Calf survival is independent of dip-tank, (b) Calf survival is independent of birth weight, (c) Calf survival is independent of calf sex, (d) Calf survival is independent of level of dam udder tick infestation, (e) Calf survival is independent of dam udder score.

LITERATURE REVIEW

2.1. Background

The domestication of animals was driven primarily by peoples' need to secure food during the time when hunting was becoming difficult and poor, thus people resorted to livestock production which freed people from the labour of collecting food and instead be available to do other forms of work (Webb, 2006). Domestication and the increasing dependence on animal agriculture prompted the developing livestock industry, focusing on increasing livestock numbers, maximizing production yield which was achieved through improved breeding, feeding, management and health of the animals (Steinfeld, 2004).

Beef production is a multimillion dollar industry worldwide with one potential trait for producers to consider, being udder quality because better udder quality reduces labour costs and increases cow longevity (Wythe, 1970; Frisch, 1982).

Newborn calves need to nurse unassisted especially in communal conditions, where assisting the calves may not be feasible. The dam udder type is one factor that affects the calf's ability to nurse. With poor udder attachment and/or teat size of either extremes will cause difficulty in nursing of the calf by the dam (Wythe, 1970; Edwards, 1982; Ventorp & Michaneck, 1992). With poor udder quality, this results in delaying colostrum consumption which is very important for calf immunity. It is therefore found that there is a high calf mortality rate in calves with dams with large teats and pendulous udder suspension (Frisch, 1982). Improving udder quality is beneficial to producers but more especially to calves because it increases the number of calves weaned (Heather Bradford, 2013). The quality and quantity of milk produced is directly dependent on the health of the cow as well as the cow's udder (Szencziova & Strapak, 2012). Disturbances which cause a drop in milk production are a major problem at dairy farms.

2.2. Udder Physiology

The mammary system is one of the most important fetal traits of the cow. Udder and teat soundness are important for a number of reasons such as labour associated with extra costs and reduced convenience, longevity which may be reduced because of injury or mastitis. Mammary soundness is equally important for calf performance because the calf's growth and development can be affected by the reduction in milk flow and low colostrum intake by newborn calves, caused by difficulty in nursing by the cow because of enlarged teats. The ideal udder has symmetrical quarters and teats that subjectively look ideal for milking. Pendulous and irregular quarters are generally the result of stretching due to repeated episodes of edema after calving or inflammation, causing for udders to be more difficult to milk and suckled by calves, but are probably not making the cow sick. It is rare that all 4 quarters would have mastitis at the same time, but common that all 4 quarters have edema. Generally an abnormal quarter will be obvious compared to the other 3 normal quarters. Abnormalities in consistency

of the glandular tissue of the udder include edema, hardening, and acute. A sound udder's characteristics are:

- An ideal udder is snugly attached
- In general smaller teat size is desirable because oversized teats are difficult for newborn calves to nurse thus difficult for colostrum intake. This leads to higher incidences of scours and decreased immunity.
- Udder suspension is also an important factor because weak udder suspension leads to pendulous effects. This means the cow's udder hangs very low to the ground subjecting the udder to serious problems and increased tick attachment and injuries.

2.3. The Cow's Mammary Gland Defense Mechanism

The defense mechanism of a lactating cow's mammary gland is mediated by a variety of non-specific and specific mechanisms which operate independently or interact to protect against udder infestations (Craven & Williams, 1985). Secretions from the mammary gland such as colostrum serve an additional function of providing the calf with passive immunity.

The teat is one of the most likely routes on which microorganisms easily enter into the mammary gland. The teat canal properties act to exclude and impede the passage of invading pathogens therefore making the teat canal the vanguard of the udder defense (Craven & Williams, 1985). Infection in its early stages is signaled by the development of inflammatory responses with a consequent flux of serum proteins and inflammatory cells. Phagocytic activity in the mammary gland clears the infection but is not always successful. If so and the microbial agents persist, then chronic inflammation ensues, allowing significant microbial toxin production with the udder leading to severe consequences (Craven & Williams, 1985).

2.4. Methods Used to Analyze Udder Health

In the past there have been different methods used to diagnose udder health and milk secretion, such as with radiology (Witzig & Hugelshofer, 1984; Witzig et al., 1984; Alacam et al., 1990). In recent years radiology has been replaced with ultrasonography, which is a non-invasive method with the ability to observe separate mammary gland structures (Stocker & Rusch, 1997; Hospes & Seeh, 1999). Telescopy is another of the different methods used to analyze udder health, allowing visualization of the papillary part of milk cistern and the teat canal but does not display the anatomical structures located close to the teat canal (Geishauer et al. 2005; Kioussis et al., 2009; Fasulkove, 2011). An indirect method used to monitor teat issue reaction via blood flow is by using infrared thermography to measure the temperature of teat tissue, and skin temperature is used as a parameter to measure the blood flow intensity of blood circulation (Hamann & Duck, 1984; Paulrud et al., 2005; Kunc et al., 2007). The cutimeter is a method used to measure teat thickness.

2.5. Ticks, Tick Physiology, Attachment and Feeding, Tick Control

Ticks have an important impact on the production of cattle because not only do they damage the cow hides and skin but also damage important organs of cattle, such as udders, scrotum and ears. Very little is known about the effect known as the 'tick worry' effect which is a suppressive effect on the appetite of the tick (Afrivet Business Management, vol.1, November 2004). In particular larger hosts animals are commonly more highly infested (Craine et al.,1995; Moore & Wilson, 2002). Heavy infestations of ticks on cattle affect both the growth and production rates of the animals resulting in lower meat and milk production. The prevention of teat and udder damage in replacement heifers and cows by multi-host ticks is an essential part of primary animal health care that should be followed on every farm where there is a predominance of tick occurrence. Udder and teat damage is the most important cause of long-term reproductive and production losses which are irreversable and untreatable once the damage is done, but it can surely be prevented.

With 825 identified tick species in the world, ticks are invertebrates and are related to spiders and insects and belong to the phylum Arthropoda group but within a group called the order *Acari* which consists mostly of mites. Ticks like mites are parasitic and feed on blood. There are two types of ticks; the soft body ticks called the Ixodidae and the hard bodied ticks called the Argasidae, because of their hard plates on their bodies.

Ticks find their hosts in different ways. Some ticks use the ambush technique whereby they live in open environments and crawl onto vegetation to wait for the passing by hosts; this is called questing. The ticks grab onto the host using its forelegs and crawls to find a suitable place on the skin to attach and feed. Other ticks such as the Amblyomma ticks are active hunters; meaning they run across the ground seeking a suitable host nearby and this makes them exophilic. Ixodes spend their whole life cycle in the host nest and attach the their host there and this makes them endophilic

All feeding of ticks at each life cycle is of a parasitic manner, by attaching to the host's skin with their hypostome and palp (mouthparts). The hypostome penetrates the skin and the palp glues to the outer epiderm. The hypostome has moveable rods called chelicerae which have sharp claws cutting a hole through the dermis and breaking the capillary vessels under the host's skin. This forms the feeding lesion, releasing blood and lymph for the tick to feed on.

The chief means of controlling tick borne diseases for livestock is via the control of ticks themselves (Kocan, 1995). Tick control is critical to the control of tick-borne diseases while the direct impact has on livestock production is also known. Tick control, today, rests on the approach of genetics and chemical acaricides. Choice of control technology implementation on tick control depends on the genotype of cattle, time between tick treatment and the animal product reaching the market, the nature of the farm and the presence or/and absence of

acaricides resistance and a host of other factors. Very important to also consider is the species of the tick to be controlled. The idea of using biological agents to control ticks is appealing even though the practical difficulties of doing so have yet to be resolved (Samish & Rahacek, 1999). The frequent use of a given acaricide can result in a tick population that has been selected for the acaricide resistance thus having to switch to a stronger and more expensive acaricide. On the other hand the intensive use of an acaricide can leave livestock vulnerable to epizootics of tick-borne disease should the system of dipping break-down. This happened in Zimbabwe in the late 1970s when the government run dipping system had to be stopped because of the war at the time. This resulted in more than one million cattle dying out of the estimated six million (Lawrence et al., 1980).

2.6. Tick Resistance

Animal diseases in general and tick and tick borne diseases (TTBD) in particular are among the many factors which directly and indirectly hamper the growth of the livestock sector and of the whole agricultural sector due to the many roles of livestock as a source of food and income through generation of employment, delivery of energy (dung, biogas), fertiliser, weed control, use of marginal lands, investment and savings as well as transport (Sansoucy, 1995).

In the past years authors (Mattioli et al., 1993, 1995; Rechar et al., 1990,1991; Spickett et al., 1989) have published results which suggest that certain cattle breeds are less susceptible to tick infestations such as tick species like *Amblyomma spp.* It is said that ticks such as *A. hebraeum* and *A. variegatum* are able to evade direct reactions of the host's immune system to their infestations. But Norval (1992) proposed that ticks avoidance behavior, skin sensitivity and increased grooming activity by Zebu, Sanga and *Bos. Indicus* cattle breeds account for the lower numbers of *A.hebraeum* and *A. variegatum* when compared to tick numbers on exotic cattle breeds like *Bos taurus*. In studies by Spickett et al. (1989) and Munchenje et al. (2008), it was found that Nguni cattle carry lower tick loads and therefore appear to be more resistant to ticks in comparison to other breeds such as Bonsmara and Angus). The lower tick count in Nguni may be related to the breed's smoother coat and shorter hairs which tend to discourage tick attachment. This is in agreement with findings by Webb and David (2002) who reported lower tick count on positions which have shorter hairs in Tsawna, Simmentaler and Brahman cattle.

2.7. Acaricides

Control is largely based on use of acaricides, however this use increases the cost of production and also results in chemical residues in milk, meat, hides and environment (Machado et al., 2010; Regitano et al., 2010). Earlier acaricides such as arsenic and chlorinated hydrocarbons, known for their high toxicity levels, have been replaced by organophosphates, amidines, synthetic pyrethroids, avermectins, flouazuron--an acarine growth regulator (Junquera et al., 1995) and, very recently, fipronil, the anti-flea compound developed as acaricide in Brazil.

Despite their well-known disadvantages, resistance, environmental pollution, residues in meat, milk, hides and skins and natural toxicity, acaricides are still the backbone of tick control as they are effective both in the short-term by cleaning the animal of ticks and in the long-term in reducing tick burdens. The spread of resistance to synthetic pyrethroids in *Boophilus microplus* in many parts of the world has forced veterinary authorities and farmers to seek new alternatives, such as amitraz and others, increasing the risk of resistance developing to these compounds. This sent a strong signal of the possible limitations of future use of chemical tick control and it is therefore essential that acaricides are managed as a precious but finite natural resource.

2.8. Immunisation Against Ticks

The use of the host's ability to produce anti-tick antibodies protecting itself partially or totally against ticks was suggested by Galun (1975). Subsequent work (Willadsen et al., 1995) has culminated in the development of a vaccine against *B. microplus*, based on tick antigen Bm86, which is now commercially available in Australia (TickGARDT[™]). The vaccine has also been tested in Brazil (Hungerford et al., 1995). This is surely one of the most important developments in tick control in recent years. A similar vaccine, developed and produced in Cuba under the name GAVAC TM, has been tested in Argentina, Brazil, Colombia, Cuba and Mexico (de la Fuente, 1995). Unfortunately, efforts to develop a vaccine against 3-host ticks, particularly *Rhipicephalus appendiculatus*, have been unsuccessful. This continues to be an important area of research at the International Centre of Insect Physiology and Ecology.

2.9. Genetic resistance

Host genetic resistance is life-long and heritable, and the degree of expression depends on the stimulation of the immune response to tick feeding. It varies between individuals, however, and its expression can be affected by external factors such as stress and nutrition. While the within-breed variation in genetic resistance to ticks could potentially be used to breed for resistance, the between-breed differences are well known in cattle, where *Bos indicus* breeds, in general, show much higher resistance than *Bos taurus* animals (Utech et al., 1978; de Castro and Newson, 1993). Norval et al. (1997) confirmed differences between breeds in resistance to *Amblyomma hebraeum* and cautioned against the use of *B. taurus* in areas where this tick and heartwater occur. A number of other breeds have been investigated for resistance to ticks (Ali & de Castro, 1993; Moran et al., 1996), with similar conclusions. The simplest form of utilisation of host genetic resistance is cross-breeding with *B. indicus* or other resistant breeds. This option has been successfully applied in Australia and parts of Latin America where European breeds have been replaced by Zebu animals. In some areas farmers are very reluctant to such change, however. In areas of Latin America farmers holding Zebu animals are responding to prevailing

market forces and changing to European breeds, with consequent intensification in tick control. In developing countries where 3-host ticks cause problems, the indigenous cattle are already resistant to ticks to a large degree and probably also to some of the tick-borne diseases (TBD). This is often disregarded as productivity is generally believed to be low. Studies in Africa have shown that when cattle in a herd are ranked for tick resistance, there is a significant cross-immunity between species (Kaiser et al., 1982; de Castro et al., 1991), suggesting that if cattle are selected for resistance against the most important tick species, this will improve the control of other species as well. In addition to the possible use of the resistance of the N'Dama breed to both ticks and trypanosomosis (Mattioli & Cassama, 1995) other suitable breeds, particularly of the Zebu type and their crosses should be promoted in an attempt to increase livestock production in Africa (Alexander et al., 1984; Hayman, 1974; Madalena, 1989). Recently a line of *Bos taurus* (Hereford X Shorthorn = Adaptaur) with very high and absolute resistance to *Boophilus microplus* in the presence of environmental stress, was identified. The resistance observed is acquired in early life in the presence of ticks and is stable, lasting for the animal's life time under the tick-challenge conditions tested (Frisch, 1994). A major gene is responsible for this phenomenon (Frisch, 1994; Kerr et al., 1994). This obviously represents a major advance in tick control that may have wide applications.

2.10. Tick Reproduction

Most Ixodides mate while attached to the host with the exception of some mating while on the vegetation. The male remains attached to the host and mates with as many female ticks as possible, while still feeding on the host. Females only mate once before they are fully engorged with blood. Once engorged they detach from the host and have enough sperm stored to fertilize their eggs of which are never laid on the host but in the environment. Female Ixodides lay between 2 000 and 20 000 eggs in a single batch. Argasides lay repeated small batches of about 500 eggs at a time.

2.11. Diseases Associated with Ticks

Ticks are important because they have adverse effects on livestock production. They parasitize a wide range of vertebrate hosts and transmit a wide variety of pathogenic agents (Tiki and Addis, 2011). Ticks are harmful parasites which have a direct effect of causing disease states in their hosts without even having any pathogens or parasites transmitted by the tick itself. Ticks such as the *Amblyomma variegatum* adults cause scarring on cattle udders and teats which reduce the suckling efficiency. Ticks are vectors, transmitting pathogenic organisms such as bacteria thus causing diseases. Regarding the indirect effects of ticks, four major tick-disease complexes are recognised affecting cattle on a world-wide basis (McCosker, 1979). A lot of money, research and other efforts is put into trying to reduce and control these pathogenic diseases through a variety of treatments and management techniques.

2.11.1. Pseudocowpox

This is probably the most common viral infection of teats, causing lesions and cutaneous damage. The infection is caused by a member of the genus *Parapoxvirus*, a DNA virus closely related to of which affects sheep. The lesions are principally found on the teats although the mouth may also be affected. Calves suckling teats of infected cows may develop lesions of the mouth and muzzle. On teats there is initially a small red papule surrounded by 0.5-1.0 cm of erythema. The center may form a vesicle that ulcerates then scabs. Typically after 10-12 days the lesion heals outwards resulting in a characteristic ring or horseshoe-shaped scab. Some 5-10% of animals may be affected on the udder too. Recovery takes 3-5 weeks but immunity is low and re-infection is common. The infection is usually chronic and spreads slowly through the herd. Acute infections occur, most commonly in newly calved heifers and animals newly introduced to the herd. Acute infections result in difficulty in milking due to discomfort to the cow. Often milk-let down is impaired. The virus can also infect the hands of the milker resulting in a condition known as 'milkers nodules, where purple nodules appear on fingers. The lesions may break down, crust and then heal without scarring. This condition is relapsing and so there may be continual cycles of infection between cows or between the milker and the cows. Diagnosis is based on the characteristic lesions on the teats of cow or the hands of the milker. The virus can be readily identified and differentiated by laboratory tests.

2.11.2. Herpes Mammillitis

Both herpes type II and herpes type IV viruses cause bovine herpes mammillitis (BHM) teat lesions. The lesions are clinically and epidemiologically similar but can be distinguished by serology. Outbreaks of BHM can make milking very difficult and are often accompanied by concurrent mastitis. The virus can survive in the environment for at least 100 days at room temperature and survives freezing and thawing. The response to infection is highly variable, from animals that simply sero-convert with no lesions, through mild lesions that heal to severe erosive lesions. The latter are slow to heal and the deep ulceration is often secondarily infected. Initially there is a painful swelling of the teat and reddening of the teat skin. Teats then develop multiple raised oedematous plaques followed by formation of irregularly shaped vesicles. The vesicles rupture within 24 hours, leaving an ulcerated surface that exudes copious serum and virus. On drying, a thick dark-red scab forms, distinguishable from the ring shaped lesions of pseudocowpox. Lesions may coalesce to affect most of the teat skin and often much of the udder skin. The extent of the ulceration and scab formation is indicative of herpes infection. Secondary bacterial infection, leading to sloughing of teat skin, is a common consequence. Lesions typically heal in 2 to 3 weeks but some ulcerated lesions may persist for months. Lesions occurring on the udder tend to be more diffuse and superficial. Once the lesions have healed there is evidence of long term immunity to the disease. Herpes infections show a seasonal pattern although this may be a weather or climate association. Tick and other Insect transmission has been suggested but not proven. Newly calved heifers, some 2-3 weeks post partum, are usually the most severely affected suggesting contagious spread at stresses associated with the first calving affect the likelihood of disease

occurring. Very young animals may sero convert. Like all herpes infections, the virus remains latent and lesions may recur.

2.11.3. Papilloma

Bovine papilloma viruses cause papillomatosis or warts on teats. Supposedly up to six separate strains of papilloma virus occur with at least two identified as the cause of warts on teats. Warts are most common on young cows although they are contagious. The most obvious and problematic warts are those that are frond-like or filamentous protruding up to 10 mm. In some newly calved heifers in some herds warts may completely obscure the teats. The warts are of most nuisance if found on the teat duct orifice affecting hygiene and milk flow. They are easily damaged and bleed, occasionally profusely. They may be secondarily infected although a direct association with mastitis is not proven. Many frond warts resolve over the first lactation, although some are persistent and may need to be removed surgically. Many teats and herds only show 'rice grain' or small, smooth and flat, white warts anywhere on the teat. These warts are rarely of any problem to milking and suckling.

2.11.4. Cowpox

The lesions develop as an erythema, forming a pustule that ruptures and then suppurates. Healing is centripetal and uncomplicated, taking up to three weeks. Life-long immunity occurs.

2.11.5. Foot and mouth Disease (FMD)

There is a need to differentiate Foot and Mouth Disease from more common viral teat infections as occasionally pustular lesions occur on teats before their appearance in the mouth. However, the rapid development of other clinical signs including profuse salivation, nasal discharge, recumbence or foot stamping will quickly lead to a more correct diagnosis. Confirmation by identification of the antigen or antibodies is essential.

2.11.6. Vesicular Stomatitis

It is transmitted by biting insects although direct transmission also occurs. Epizootics have been described every 5-10 years. The severity of the disease is variable but clinical signs closely resemble those of Foot and Mouth Disease. Lesions, however, usually develop on one site only of the mouth, the feet or the teats although there is excessive salivation. Laboratory confirmation of virus is essential to distinguish the infection from FMD.

2.12. Fungi

2.12.1. Ringworm

The infection of skin keratin by the fungus *Trichophyton verrucosum* occasionally spreads to the teat. The condition is very unlikely to be confined to the teats and udder and should be easily

recognised from the characteristic grey-white and ash-like skin encrustation usually on the thorax and limbs of adult cows. The infection is highly contagious and likely to spread. Usually herd immunity develops but reoccurrence is typical when new susceptible animals are introduced, especially as spores survive for several years.

2.12.2. Bacteria

Bacterial infections of teat skin are significantly more prevalent than any viral infections, and of much more importance to both beef and dairy economics as a major source of new intra mammary infections and clinical mastitis, both in lactating and non-lactating cows. Untreated teat lesions are rapidly colonized by any, or all, of various bacteria. *Staphylococcus aureus*, *Streptococcus dysgalactiae* and *Arcanobacterium pyogenes* are ubiquitous on the skin of dairy cows. They readily colonize any lesion, traumatic or infectious. It was shown clearly some 30 years ago that chapped teats were highly likely to be infected with *Staphylococcus aureus* or *Streptococcus dysgalactiae*, and that such infections were closely associated with high new infection rates and frequent cases of clinical mastitis (Kingwill et al., 1970). The disinfectants developed for teat treatment are usually effective at eliminating bacteria and viruses from lesions and usually contain emollients to promote skin healing. Primary bacterial infections of skin are likely to be purulent, presenting as discrete pustules or as impetigo. They may frequently be necrotizing, especially when *S. aureus* is involved. One particularly important bacterial infection is colonization of the damaged teat orifice, by *Fusiformis necrophorum*. The condition, known as 'blackspot', is easily recognizable from the colour of the scab formed. This anaerobic bacterium is highly necrotizing and erodes the orifice. The teat orifice may become occluded leading to incomplete and very slow milking. Blackspot is a major risk factor to intra mammary infection by other bacteria. More complicated lesions result from secondary bacterial infections causing significant changes in the appearance of the primary lesions making diagnosis difficult. Scoring Infections

When assessing teat condition, all lesions and infections observed should be recorded. Few lesions and no infections should be found if good husbandry is being applied. Indeed identification of any infectious lesions is unlikely in routine teat condition monitoring unless they have occurred as a consequence of traumatic teat injury such as a cut or a tramp. Bacterial infections are difficult to diagnose from clinical signs unless they are chronic secondary infections. Again they are symptomatic of poor husbandry. If any lesions caused by milking or environmental exposure have progressed to become severe or chronic then management is at fault and this is not a new occurrence on the farm. The occurrence of any infectious lesions and making a correct identification should never be underestimated. A specific diagnosis is essential to indicate the strategic significance of the problem (especially for FMD), to identify the risk for the rest of the herd and the farm staff, and to design a treatment program to alleviate the condition and remove the causes. When lesions appear severe or affect more than a few teats then remedial action is necessary.

2.13. Abundant Tick Species Found in Mpumalanga cattle

2.13.1. *Amblyomma hebraeum*

These ticks are also known as the South African bont tick because of the coloured pattern on their scrotum. They are notoriously known as the main vector of *Ehrlichis ruminantum* and a cause of direct tissue damage on the host. The adult tick prefer large hosts such as cattle and large wild ruminants such as giraffes and buffaloes, but do also infest small stock (sheep and goats). They are commonly found on hairless areas on the host, predominantly on udders, under the tail, lower perennial region and on genitalia. With the immature ticks simultaneously feeding on the same host as with the mature ticks.

There are three-host ticks; the adults and the nymphs are hunters, scattering on the ground waiting for a suitable host to attach onto. The females lay up to 20 000 eggs which hatch into larvae and wait for host attachment to engorge for 7-14 days. The male tick secretes pheromones, attracting females for mating, but at the same time this attracts other male ticks and nymphs, causing host infestation. Once the female tick is engorged they detach but males stay on the host for up to 3 months. In Mpumalanga, Kwa-Zulu Natal and Limpopo, the tick's life cycle continues throughout the year because they thrive in Mediterranean and temperate climatic regions, requiring moisture, warmth and bush.

2.13.2. *Rhipicephalus (boophilus) microplus*

Simply known as the cattle tick because of its accidental spreading from cattle ranch to cattle ranch on commercial cattle transportation. Cattle are most probably the only effective host of the tick, provided cattle are present together with other livestock and wildlife animals then other animals can also be infested.

The *Rhipicephalus microplus* is a one-host tick with a monotropical behavior. The time spent by the three stages on the host is about 3 weeks and egg laying is completed by week 4.

The ticks are known for transmission of protozoans *Ba.bovis* and *Ba.bigemina* which cause bovine babesiosis (redwater disease) in cattle. Heavily infested cattle lead to commercially important damages to the hide because of the formation of scar tissue (granuloma). In South Africa the ticks are predominantly found in the Eastern and Western Cape regions but there is saturation in the Mpumalanga and Limpopo provinces.

Viral infections vary in the severity of the damage caused, in infectivity and in frequency of occurrence.

2.14. Influence of Heifer's and/or Dam's Nutritional Requirements on Calves Growth and Development

The adaptation of animals to different levels of nutrition is a powerful tool that breeders in large areas of the world have been exploiting with evident advantage (Chilliard et al., 2000;

Blanc et al., 2004). Body condition score (BCS) is the best practical indicator to evaluate and manage the body reserves (Bocquier et al., 1998; Croston & Pollot, 1994). However first the full understanding of the physiological and metabolic procedures that occur in the body of the animal in order to utilize the feed is to be understood. For example, using blood metabolites as an indicator and a helpful predictor to fully optimize feeding programs. In cows excessive amounts of lipids during gestation; the catabolism of these lipids occur before parturition and later dramatically increase afterwards. This is influenced by the cow's ability to produce milk; its energy intake levels and its endocrine environment (Rukkwamsuk et al., 1998). However there are many incidences of over-conditioning and overfeeding of cows during the dry period and therefore the cows develop hepatic lipidosis after parturition which leads to triacylglycerols (TAG) in the liver as the cow's liver is unable to increase low lipoprotein production density during early lactation. Cows which are overfed tend to gain more body weight (BW) and they lose more BW the first four weeks after parturition and this leads to putting the lactating cows in a negative energy balance (Rukkwamsuk et al., 1998). This will affect the newly born calf because now the cow is at a negative energy balance meaning she is unable to synthesize and produce milk for the highly demanding suckling calf. The calf's growth and development is thus hindered because it is not receiving and ingesting adequate and the essential nutrients needed for its growth and development.

Overfeeding of cows during gestation may also lead to causing a metabolic disorder called dystocia which causes a fatty birthing canal. Dystocia impacts production fertility and cow and calf mortality and morbidity (Dematawewa & Berger, 1997). Dystocia also increases the likelihood of both the cow and calf to develop respiratory and digestive disorders (Lombard et al., 2003, 2007; Oltenacu et al., 1988) which increases the cows stress levels and negatively impacts the cow's ability to maintain not only its body but also the duration of gestation, the developing fetus and milk production for the calf after parturition.

2.15. Defense Mechanisms for Calve Survival

2.15.1. Colostrum as first defense

Prevention of teat and udder damage is one of the best examples of what can be achieved by implementing primary animal health care with the animal handler being at the cornerstone. A clean and healthy udder and teats which are functional and produces milk daily results in producing and grooming a healthy, fast-growing calf with the cow's colostrum being a vital initial factor in tackling the calf's resistance against diseases for the first 3 months of life (if the calf suckles within the first 6 hours after birth). Milk as a whole is also important because it provides the calf with essential nutrients especially during the first 6-7 months of the calf's life when it cannot synthesis and digests these nutrients on its own because of the under-developed rumen. But the most important aspect in calf management is colostrum availability and intake from the cows to the calves. The calf is born without an active immune system and

thus needs to develop immunity and defend itself from invading pathogens. Colostrum is a source of passive immunity for the calf. It is of vital importance that the calf ingests colostrum the first 6 hours after birth because it is entirely dependent on the colostral immunoglobulins provided by colostrum in the milk, to protect the calf from incidences of pathogenic invasions and diseases. In addition to colostrum's protective characteristics from diseases, colostrum also provides high nutrition for growth and development. High fat content for heat production, insulation and also a source of energy for the calf. Colostrum also has growth factors and hormone initiating functionality, development and growth of the digestive tract which is important for the future of the calf as it will be introduced to solid diets in the future.

2.15.2. Rumen development of young calf

The ruminant's stomach is divided into four stomach compartments, and the most important being the rumen. The feeding program for the calf needs to be aimed at rapidly and efficiently establishing a fully functional ruminant digestive system because this influences the nutrient availability and utilization for the body's secondary function on growth rate. Considerable interest has been shown in the development of rumen microbial populations in calves kept on different rations and under varying conditions of management (Pounden & Hibbs, 1950; Bryant & Small, 1960). Pounden and Hibbs (1948) and Eddie, Hobson and Mann (1959) have also noted the significance of the ration in regulating the pH of the rumen and hence the microbial population in calves have demonstrated the relationship between minimum rumen pH and aliate numbers in the mature calves.

The calves' rumen has ciliate as early as 9 days old which is the time when rumination is considered to begin (Walker, 1959). By feeding young calves milk (or milk solids) by teat, encourages the maintenance of high pH in the calf's rumen and this stimulate early development of ciliates in the calves It was also found that by reducing milk intake and increasing the ingestion of concentrates at an early age causes for the decreased ciliates and they disappear (Margaret, 1969). This will negatively impact the calves' digestive ability of pasture at a later stage. Calve develop a mixed ciliated population at a very early stage given a high pH in the rumen (Margaret, 1961).

At weaning, calves are completely off milk and only ingest concentrates, hay and water which requires the development of ruminant stomach (Stobo et al., 1965). Previous studies on the influence of dietary factors in the anatomical development of the rumen have been made on calves given milk until at least 7 weeks of age (Warner, Flatt & Loosli, 1956) or 12 weeks of age (Brownlee, 1956) and which received in the main diets consisting solely of concentrates or of hay. It was suggested that an actively metabolizing rumen was necessary for the absorption of volatile fatty acids (VFA), (Armstrong, Blaxter & Graham, 1957). This could lead to the stimulation of the absorptive ability of the mature rumen (Sutton, McGilliard & Jacobson, 1963). The growth rate of the calf is thus dependent on the development of the rumen.

2.16. Nutritional Needs for Calf Growth and Development

Little is known about body growth rates during the period between birth and approximately 4 months of age that encourage maximal mammary development and future milk production (Brown et al., 2005). In calves before weaning, 2 studies have been reported that increased intake of whole milk was related to higher future milk production (Brown et al., 2005). Study demonstrates that increased energy and protein intake is associated with accelerated calf growth of mammary parenchyma in calves. The stimulation of anatomical and physiological development by ruminal volatile fatty acids (VFA) suggests a relationship between ruminal development and microbial activity. The establishment of the ruminal bacterial population is dependent on the diet of the calf (Beharka et al., 1998).

Poor nutrition is one of the main factors contributing to poor and low reproductivity of the cows and high mortality rates of weaned calves. Young calves grow slowly and this delays their sexual maturity and fertility. Thus it is of vital importance to make sure the pastures the cattle graze on is of good quality because poor pasture causes the cattle to suffer from protein, energy and mineral deficiencies (Fajersson et al., 1991). By studying the effect of proper nutrition of both the heifers/ cows and the calves, it makes it easier to evaluate the effect it has on weight gain, BCS, age at puberty and maturity.

2.17. Genetic Influences on the Calf's Growth and Development

The mortality of calves from birth to weaning reduces beef farm income and adds significantly to beef production costs (Philipsson, 1976; Wittum et al., 1993). It is thus necessary to integrate calf survival traits in the definition of an overall breeding objective in beef cattle (Goyache et al., 2003).

Heterosis effects of birth weight and survival percentage have been evaluated as traits of the dam in F2 progeny of F1 dams and F3 and F4 progeny of F2 and F3 dams in three composite populations in beef cattle (Greory et al., 1991). Calves with difficult births with 2 year old dams were significantly heavier at birth and had significantly lower survival and weaning survival than the calves with dams that did not experience difficulty (Gregory et al., 1991).

Heterosis achieved through continuous crossbreeding can increase weight of calf weaned per cow exposed to breeding by 20% (Gregory & Cundiff, 1980). The calf- human interactions also play a role in the animal's survival in the production unit. The extent to which calves are in contact with humans affects their subsequent behavior (Boivin et al., 1994). It has been shown in cattle that consistent contact with humans makes animals less fearful and easier to handle (Boivin et al., 1990). This is related to the stress levels the animal has during its rearing phase and thus has an influence on its growth and development to weaning age and year old age.

Heritability estimates of all longevity traits are low, yet improvements of the traits are permanent and cumulative. Early survival is shown to be favourable correlated with the

productive life survival and milk yield traits and estimated correlated response of early survival of the current UK breeding goal is also favourable (Pritchard et al., 2013). Increasing the survival of heifers during the rearing period is expected not only to have economic benefits but also to have social and environmental advantages (Pritchard et al., 2013)

The difference between dairy and beef analyses is that maternal effects (genetic or environmental) are likely to play a greater part in beef animals. Heritability estimates of calf survival at weaning were 0.05 in multi-breed (Guerra et al., 2010) and 0.03 in Australiana de los Valles (Cervantes et al., 2010) beef cattle, which were higher than the present study (Pritchard et al., 2013). The low heritability of heifer survival can be explained by large environmental influences, as well as its classification as a binary trait (Pritchard et al., 2013). Heifer losses could be combated quickly by improving the calf environment through better environment (Pritchard et al., 2013).

Survival traits at younger ages may simultaneously select against gastro-intestinal and respiratory diseases (Pritchard et al., 2013). Early survival was shown to be favourably correlated with the productive life survival and milk yield traits and estimates correlated response of early survival of current breeding goals favourably set up (Pritchard et al., 2013).

2.18. Calf Environmental Management at Weaning

Weaning of calves typically involves both the dietary and social changes as the transition from milk to solid feed normally accompanied by reduced contact with the dam (Jasper et al., 2007). Calves differ with their adaptability to the environment, as some would adjust well to new forms of feed, such as solids, then others. Changes in diet, environment and social relationships are often stressful for the young (Fraser et al., 1998). As shown by pronounced physiological changes (decreased food intake, growth check and gastrointestinal dysfunctions) and behavioural responses (including increased activity and vocalization). Thus weaning can have negative effects on both wellbeing and production.

Recent evidence suggests that weaning distress in beef cattle is aggravated by simultaneously disrupting both nutritional and social aspects (Jasper et al., 2007). Results have indicated that non-nutritional factors have an influence on weaning stress, but it is not clear which non-nutritional factors play a role even though several possibilities exist (Jasper et al., 2007).

It is suspected that the change from milk to warm water and solid diets could cause satiety in the gut fill, but metabolites and hormonal changes in blood also affect satiety (Ingvarsten & Anderson, 2000). Social factors could also cause distress in calves, such as the change in familiar routines or objects.

In the subtropical and tropical environments such as South Africa we find relatively high incidences of droughts occurring. One way to manage weaning success is by weaning calves early as this will be to avoid overstocking and utilization of forage thus maintaining the reproductive performance of cows and the growth and development of calves (Manthis &

Encinias, 2005). The early weaning of calves is one way farmers can reduce the forage needs of the cow- calf enterprise and at the same time improve cow- calf conditions and reproductive performance. The objective in calf weaning and rearing is to make sure the cow can fall back into reproductive cycle and the calf survives weaning and reached maturity weight at the right age. Normal weaning age is between ages of 6 and 8 months, depending on the production system and their practices. This allows for the calf to accumulate and build up adequate muscles, fats, growth and development to survive weaning when it is separated from its mother.

3. METHODS AND MATERIALS

3.1. Study area

This study was conducted in a rural community that forms part of the Mnisi Traditional Authority, located in the north-eastern corner of Bushbuckridge Local Municipality, Mpumalanga Province, South Africa. The study area is bordered by wildlife game reserves including Sabisand, Timbavati, Manyeleti and the Kruger National Park (Figure 3.1). The area falls within the administrative area of Mpumalanga Veterinary Services (MVS) State Veterinary Office: Bushbuckridge East-Orpen (SV BBR EO). The SV BBR EO is divided into three wards: Bushbuckridge-1 (B1), Bushbuckridge-2 (B2) and Bushbuckridge-3 (B3) (Malan, 2015). Each ward comprises five dip-tanks under the authority of an individual animal health technician (AHT) who is responsible for the cattle dipping and inspection sessions at the communal dip tanks on a weekly basis (one dip-tank per day).

3.2. Dip tank layout

Among the 3 wards of SV BBR E O, Ward B1 was selected for the main study (cohort study). The dip-tanks in Ward B1 are called Clare B, Clare A, Welverdiend A, Welverdiend B and Thlavekisa which are visited on a weekly basis (Monday to Friday) according to the following schedule

- Mondays- Clare B
- Tuesdays- Clare A
- Wednesdays- Welverdiend A
- Thursdays- Welverdiend B
- Fridays- Thlavekisa

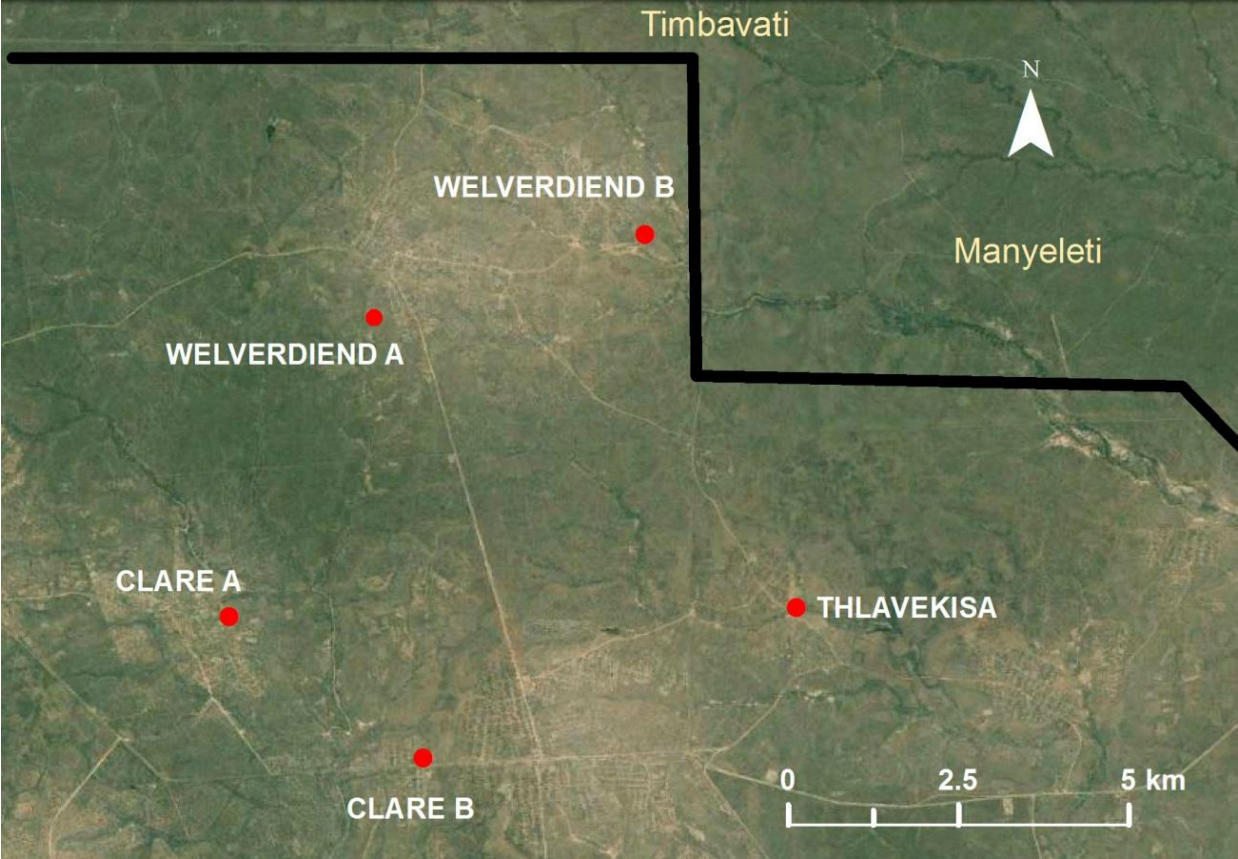


Figure 3.1: Map of Ward B1 dip tanks, bordered by the Manyeleti and Timbavati game reserve fence. The black line represents the fence of the reserves (Google Earth maps, May 2014)

3.3. Study design

The study took place from 29 July 2013 to 29 August 2014. The study had two components: a cross-sectional and a cohort study.

3.3.1. Cross sectional study

The cross-sectional study was conducted at ward B2, from 29 July 2013 – 2 August 2013. The ward is made up of 5 dip tanks of which the AHT visited on a weekly basis on designated days; Eglington (Monday), Share (Tuesday), Utah Scheme (Wednesday), Shorty (Thursday) and Athol (Friday). Prior to selection of cows, a meeting was held with the representative of the animal health technicians (AHT) of ward B2 for the permission to conduct the research and also to explain the purpose of the study. Cattle owners who participated in the study were given an oral consent.

A systematic random sample of cows brought to the dip tank by farmers were consecutively selected as they entered into the crush pen. Every 10th cow was selected and its udder was palpated irrespective of whether it had a calf or not, or was in gestation or not.

3.3.1.1. Udder palpation procedures

Palpation of the udder quarters and teats was performed for any abnormalities and tick infestation. Palpation of the udder was performed in the following order (Figure 3.2):

1. Approach animal from behind, gently talking to animal and placing hand on the rump before starting the udder palpation procedure.
2. Palpation of left front (LF) quarter.
3. Palpation of the right front (RF) quarter.
4. Palpation of the left hind (LH) quarter.
5. Palpation of the right hind (RH) quarter.

The presence of warts, nodules, lesions, edema, atrophy and fibrosis was determined. The presence of any one of the characteristics was designated with a score of 1 and if it was not present on any of the quarters it was assigned a score of 0. Dams that were unable to be palpated had number 99 assigned to the score sheet. The teats on each quarter were also palpated individually in the same order as udder palpation. Canal openings were also inspected. The presence of warts, nodules, lesions and deformities on the teats was determined. The presence of any one of the characters was designated with 1 and if it was not present on any of the teats it was assigned a score of 0. Dam teats that were unable to be palpated had the number 99 assigned to the score sheet.



Figure 3.2: Dam udder inspections and evaluations

3.3.1.2. Udder symmetry

Udder symmetry was determined by subjective evaluation of whether the udder looked symmetrical or not. Symmetrical udders were scored 1 and asymmetrical udders were scored 2.

3.3.1.3. Cow udder score (CUS)

The cow udder score (CUS) was an ordinal score from 0- 3:

- 0= udder had no signs of damage
- 1= udder had low level of damage
- 2= udder had moderate level of damage
- 3= udder was heavily damaged.

CUS was determined by adding all the palpation scores (udder and teats) and udder symmetry score.

- If the total sum of all palpations scores on dam udder and teat was 0, CUS=0.
- If the total sum of dam udder palpation scores added up to between 1 and 2, CUS=1.

- If the sum of all palpation scores was 3 or 4, CUS=2.
- If the sum of all palpation scores was 5 or above, CUS=3.

3.3.1.4. Tick attachment scoring criteria

Tick attachment scores were an ordinal score system, from 0- 3:

- 0 = no tick attachment on udders
- 1 = low tick infestation on udders
- 2 = moderate tick infestation on udders
- 3 = heavily tick infested udders

3.4.5. Body condition score

The cow's body condition scores (BCS) was subjectively done using two independent operators, the researcher and research assistant. Because the BCS was done on a range of cattle (beef, dairy and mixed), the USA scoring range of 1 - 9 was used, whereby very thin cows are scored the number 1 and obese cows are scored the number 9 (Corah, 1989).

3.4. Cohort study

The cohort study was conducted from 12 August 2013 - 29 August 2014. Prior to selection of cows, a meeting was held with the State vet and the representative of the animal health technicians (AHT) of ward B1 for the permission to conduct the research and also to explain the purpose of the study. Cattle owners who participated in the study were given a consent form in Xitsonga and English. Participants at each dip-tank were selected as representatives of their own dip tank within ward B1.

Dams with newborn calves between 7 days to 14 days old were selected. The dam data collected included: dip tank, ear tag, breed-type; body condition score, heart girth; age category; parity; udder scoring classification and udder tick infestation levels. CUS and TAC scoring were performed as described in Section 3.3.

3.4.1. Dam breed-types

The breed of the dam was noted as Sanga breed (ST), Brahman breed (BT) and Brahman crosses (BC). The BT and BC breeds were grouped together into one category as Brahman-type (BR) and the ST became the Sanga-type (S).

3.4.2. Dam age category

Dams were grouped into two age categories. Dams of ages 4 years and younger (≤ 4 years old) were assigned to age category 1. Dams aged older than 4 years (>4 years old) were assigned to age category 2.

3.4.3. Dam body condition score (BCS)

The cow's body condition score (BCS) was subjectively done using two independent operators, the researcher and research assistant. Because the BCS was done on a range of cattle (beef, dairy and mixed), the USA scoring range of 1 - 9 was used, whereby very thin cows are scored the number 1 and obese cows are scored the number 9 (Corah, 1989).

3.4.4. Dam heart girth (HG)

The dam's heart girth was measured as the circumference of the animal at the location of the animal's heart. The length of the animal's body and its hip height were also measured in centimeters.

3.4.5. Enrolment of calves

Calves remained with their dams in the raceway while the AHT did dam health inspections. Thereafter, for safety reason, calves were separated from dams. Research assistants tagged and tattooed calves in the right and left ear respectively. Calf breed type was determined. The calves were grouped into two breed types- namely Sanga-types (S) and Brahman-types (BR). The sex of calves was determined as male (M) or female (F).

Farmers gave the date of birth of calves. Calves were weighed in kilograms(kg) using the salter gauge scale and block and tackle method (Figure 3.3).



Figure 3.3: Weighing of calf using the block and tackle system and salter gauge scale

3.4.6. Follow-up calves

Calves were weighed every 4 weeks for 7 months. Cows and calves were reunited and released back to the rest of the herd. Calves, that did not come to the dip-tank on designated follow-up date of dip-tank inspections, were weighed the following week. Calves, that did not come to dip-tank twice consecutively on designated date of dip-tank inspection, were weighed on their next designated weighing date. Calf average daily gain (ADG; kg/day) was calculated as the final weight minus the initial weight, divided by the number of days between the initial and final weights. In the event of a death of a calf, the date of death was recorded from the farmer.

3.5 Data Analysis

The software used for analysis was the R software (R Core Team, 2017), using the *car* and *perturb* packages (Fox and Weisberg, 2011; Hendrickx, 2012).

3.5.1. Description of variables

Descriptive statistics (frequency for categorical variable, mean and standard deviation for continuous variables) were done for the following variables:

- ADG
- TAC (tick attachment score)
- CUS (cow udder score)

- Dip tank
- Dam breed
- Dam age category
- Dam parity
- BCS
- Dam breed
- Calf breed
- Calf sex
- Birth month
- Weaning month
- Calf initial weight

3.5.2. Evaluation of the relationship of dam and calf factors on calf average daily gain (ADG)

To evaluate the impact of TAS and CUS on ADG, univariate linear regressions were performed. ADG was the outcome and TAS and CUS were included as explanatory variables. Other univariate regressions were run to evaluate the impact of other covariates:

- Dip-tank
- Age of the dam
- Parity
- BCS
- HG
- Breed of cow
- Month of birth
- Sex of the calf
- Breed of the calf
- Weight of the calf at birth

3.5.3. Factors associated with dam CUS and TAC

To evaluate factors that may have an influence on dam TAC and dam CUS, ordinal regression was run. The following variables were tested:

- Dip-tank
- Age category
- Parity
- BCS
- HG
- Breed

3.5.4. Survival analyses

A survival analysis was performed to evaluate the impact of TAS and CUS on the mortality of calves. Event was set as death of the calf and time to event was the age at death (in days). The model was a Cox proportional hazard ratio model. Other covariates were also tested in the survival model: sex of the calf, dip-tank of birth and weight at birth.

3.6. Ethics statement

The Senate Committee for Research Ethics advises that all animal studies have to be approved by the Animal and Ethics Committee of the University of Pretoria. This study falls within the study title 'Livestock production and animal health management systems in communal farming areas in the wildlife-livestock interface in southern Africa'. The study protocol is AEC- V055-13.

CHAPTER 4: RESULTS

4.1. CROSS SECTIONAL STUDY RESULTS

During the cross sectional study at ward B2 in the Mnisi community, 192 cows were examined over one week. Table 4.1 and Figure 4.1 show the distribution of the different teat and quarter damages on cow udders. Table 4.2 reveals that approximately 2.6% of cows were not evaluated for tick attachment (TAS). Sixty four percent of cows evaluated had a low tick attachment score (TAS=1) and approximately 20% of cows were moderately infested with ticks (TAS=2). The distribution of cow udder scores revealed a numerically similar distribution, 30.2% of cows had a CUS of 1.

Table 4.1 shows the total cows evaluated for udder damage, 6.5% of cows had some degree of quarter or teat damage to their udder, with 82% of cow udders being symmetrical in form and shape. Figure 4.1 shows the distribution of the collective teat and quarter damage scores to cow udder. The average score for udder damage is 3.5 and the median is 3.82.

Table 4.1: Frequency distribution of different udder (teat and quarter) damage of cows evaluated at ward B2 dip-tanks in the Mnisi community

Teat/Quarter (n=192)	No Damage		Damage		NE	
LF_teat_nodules	145	(72.86%)	40	(20.10%)	7	(3.52%)
RF_teat_nodules	140	(70.35%)	45	(22.61%)	7	(3.52%)
LH_teat_nodules	160	(80.40%)	25	(12.56%)	7	(3.52%)
RH_teat_nodules	154	(77.39%)	31	(15.58%)	7	(3.52%)
LF_teat_opening	181	(90.95%)	4	(2.01%)	7	(3.52%)
RF_teat_opening	183	(91.96%)	2	(1.01%)	7	(3.52%)
LH_teat_opening	184	(92.46%)	1	(0.50%)	7	(3.52%)
RH_teat_opening	181	(90.95%)	4	(2.01%)	7	(3.52%)
LF_teat_warts	164	(82.41%)	21	(10.55%)	7	(3.52%)
RF_teat_warts	174	(87.44%)	11	(5.53%)	7	(3.52%)
LH_teat_warts	173	(86.93%)	12	(6.03%)	7	(3.52%)
RH_teat_warts	176	(88.44%)	9	(4.52%)	7	(3.52%)
LF_teat_lesions	166	(83.42%)	19	(9.55%)	7	(3.52%)
RF_teat_lesions	172	(86.43%)	13	(6.53%)	7	(3.52%)
LH_teat_lesions	169	(84.92%)	16	(8.04%)	7	(3.52%)
RH_teat_lesions	173	(86.93%)	12	(6.03%)	7	(3.52%)
LF_quarter_warts	182	(91.46%)	3	(1.51%)	7	(3.52%)
RF_quarter_warts	183	(91.96%)	2	(1.01%)	7	(3.52%)
LH_quarter_warts	182	(91.46%)	3	(1.51%)	7	(3.52%)
RH_quarter_warts	183	(91.96%)	2	(1.01%)	7	(3.52%)
LF_quarter_lesions	181	(90.95%)	4	(2.01%)	7	(3.52%)
RF_quarter_lesions	182	(91.46%)	3	(1.51%)	7	(3.52%)
LH_quarter_lesions	176	(88.44%)	9	(4.52%)	7	(3.52%)
RH_quarter_lesions	180	(90.45%)	5	(2.51%)	7	(3.52%)
LF_quarter_odema	184	(92.46%)	1	(0.50%)	7	(3.52%)
RF_quarter_odema	183	(91.96%)	2	(1.01%)	7	(3.52%)
LH_quarter_odema	173	(86.93%)	12	(6.03%)	7	(3.52%)
RH_quarter_odema	178	(89.45%)	7	(3.52%)	7	(3.52%)
LF_quarter_atrophy	174	(87.44%)	11	(5.53%)	7	(3.52%)
RF_quarter_atrophy	177	(88.94%)	8	(4.02%)	7	(3.52%)
LH_quarter_atrophy	164	(82.41%)	21	(10.55%)	7	(3.52%)
RH_quarter_atrophy	174	(87.44%)	11	(5.53%)	7	(3.52%)
LF_quarter_fibrosis	183	(91.96%)	2	(1.01%)	7	(3.52%)
RF_quarter_fibrosis	184	(92.46%)	1	(0.50%)	7	(3.52%)
LH_quarter_fibrosis	178	(89.45%)	7	(3.52%)	7	(3.52%)
RH_quarter_fibrosis	181	(90.95%)	4	(2.01%)	7	(3.52%)

LF_quarter_nodules	151 (75.88%)	34 (17.09%)	7 (3.52%)
RF_quarter_nodules	157 (78.89%)	28 (14.07%)	7 (3.52%)
LH_quarter_nodules	146 (73.37%)	39 (19.60%)	7 (3.52%)
RH_quarter_nodules	159 (79.90%)	26 (13.07%)	7 (3.52%)
Udder_symmetry	163 (81.91%)	21 (10.55%)	8 (4.02%)
Average	172 (86.44%)	13 (6.51%)	7 (3.53%)

NE~ not evaluated

Figure 4.1 represents the number of cows with the different types of damage to their udders. Of the total cows evaluated, 85% of cows showed to have symmetrical udder quarters. Most of the udder damage that occurred was the prevalence of nodules on the teats and on the quarters, 100 cows had nodules on their teats and 88 cows had nodules on their quarters. Approximately 25% of cows had warts and lesions on their teats. The figure shows that few cows had damage to their quarters.

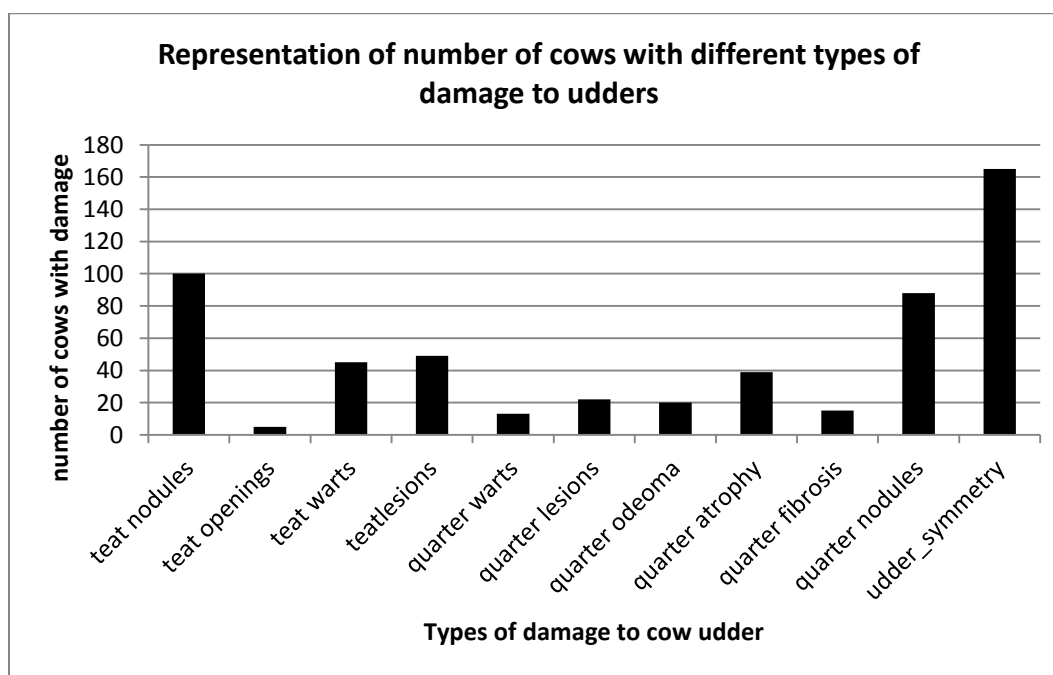


Figure 4.1. Distribution of number of cows with different types of damage to the udder.

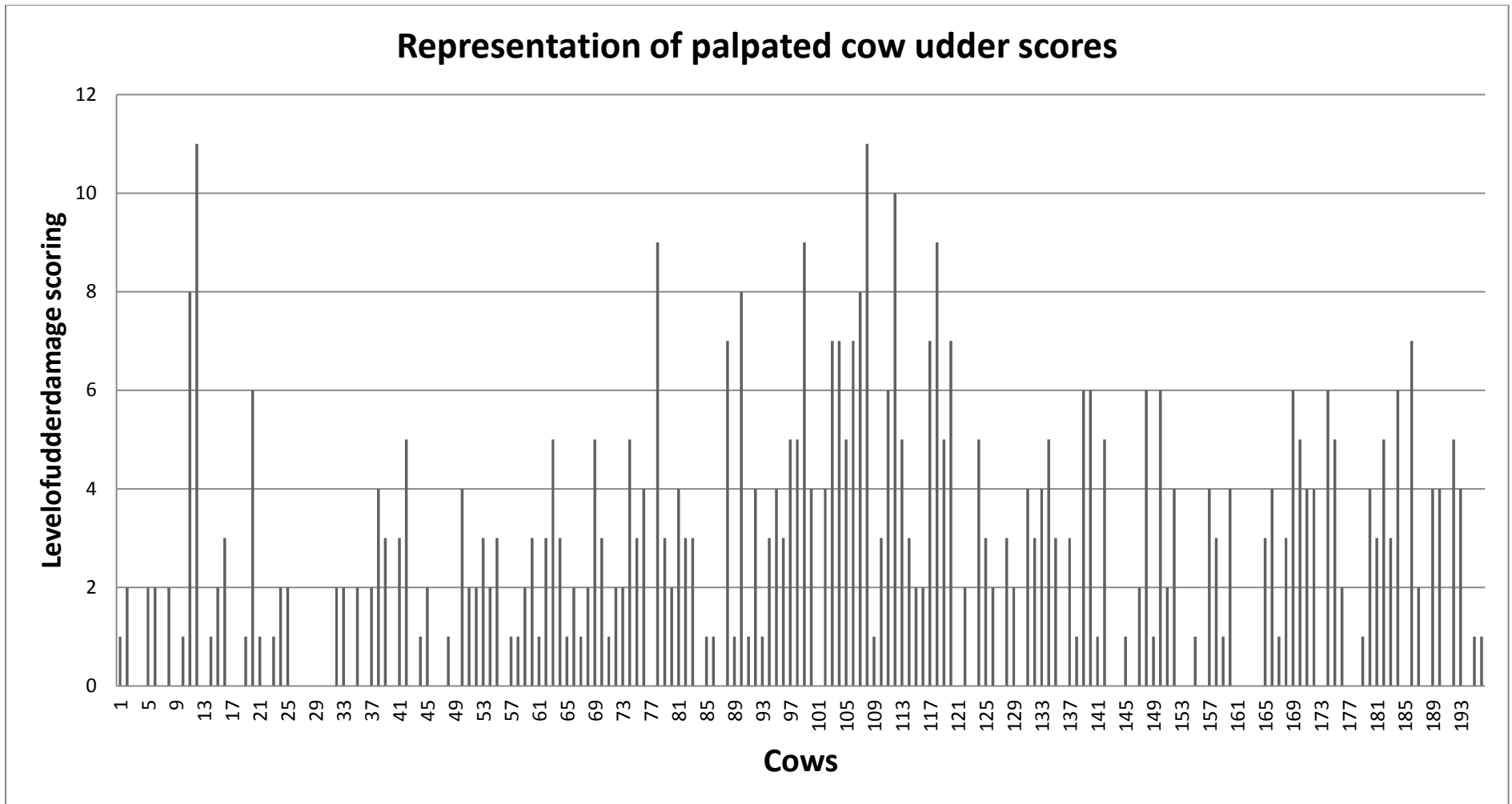


Figure 4.2. Distribution of total scores for CUS score ranking obtained for each cow when all the palpation scores were summed

Table 4.2: Frequency distribution showing level of tick attachment on udders (TAS) and cow udder score (CUS) on cows evaluated at ward B2 dip-tanks in the Mnisi community

Scores (n=192)	TAS	CUS
0	27 (14.06%)	46 (23.96%)
1	123 (64.06%)	58 (30.21%)
2	37 (19.27%)	47 (24.48%)
3	0 (0.00%)	41 (21.35%)
NE	5 (2.60%)	0 (0.00%)

TAS~ tick attachment score

CUS~ cow udder score

0~ no attachment or damage

1~ low attachment or damage

2 ~ moderate attachment or damage

3 ~ highly attached or damaged

NE~ not evaluated

The body condition scores (BCS) and cow udder scores (CUS) are summarized in Table 4.3. Cows evaluated had BCS of between 3 to 6. Fifty one percent of cows evaluated had BCS of 5, which was the median value and the interquartile (IQR) range was 4 to 5. One cow was not evaluated for BCS due to unavailability. The CUS results for cows at the dip-tanks revealed that 24% of cows had a CUS of 0, 31% of cows had a CUS of 1, 24% of cows had a CUS of 2 and 21% of cows had a CUS of 4. The median value for CUS was 4 and the IQR range was 1 to 2.

Table 4.3: Frequency distribution of body condition scores (BCS) and cow udder scores (CUS) of cows evaluated at dip-tanks in the Mnisi community

Cow BCS (n=192)			CUS (n=192)		
	Number	Percentage		Number	Percentage
3	2	1	0	46	24
4	56	29	1	59	31
5	98	51	2	46	24
6	35	18	3	41	21
NE	1	0.5			

NE~ not evaluated

4.2. COHORT STUDY RESULTS

4.2.1 Description of study population

A total of 157 cows with their calves (e.g. 157 calves) were enrolled at five different dip-tanks in the Mnisi community.

4.2.2 Description of dam population

The frequency distribution of dams from different cattle breeds sampled at different dip-tanks is presented in Table 4.4. A similar number of dams were sampled at the different dip-tanks. This provided a relatively balanced sample population for comparisons between dip-tanks. Overall there were a similar number of dams of the Brahman and Sanga breed types, but the proportions differed by dip-tank. Dip-tanks 1, 2 and 3 had a higher proportion of Brahman-type, while dip-tanks 4 and 5 had a higher proportion of Sanga-types.

The frequency distribution of cow age categories and the parities of cows at the different dip-tanks are provided in Table 4.5 and Table 4.6. Twenty-one percent (33) of dams were ≤ 4 years and 79% (124) of dams were > 4 years. Most of dams whose parity was recorded had calved down more than once (73/99; 73.7%) while the minority (26/99; 26.3%) could have been heifers and only calved down once.

The level of infestation on dam udders (tick attachment score, TAS) at the different dip-tanks is presented in Table 4.7. Overall, 62% of dam udders had a low tick infestation (TAS = 1), and 33% of dams had a moderate level of tick infestation on their udders (TAS = 2). There was a fairly similar distribution of CUS (Table 4.8) among the dams, with 24% of dams with CUS 0, 30% with

CUS 1, 22% with CUS 2 and 24% with CUS 3. Dip-tank 3 had the highest proportion of dams with severely damaged udders (48%).

Table 4.4: Frequency distribution of dam breeds per dip-tank

Dip-tank	Number of Dams	Breed-type	
		Brahman	Sanga
1	48	28 (58.3%)	20 (41.7%)
2	24	15 (62.5%)	9 (37.5%)
3	25	14 (56.0%)	11 (44.0%)
4	34	11 (32.4%)	23 (67.6%)
5	26	11 (42.3%)	15 (57.7%)
Totals	157	79 (50.3%)	78 (49.7%)

Table 4.5: Frequency distribution of cow age category at different dip-tanks in sample of 157 studied dams (Age category 1: ≤ 4years of age; Age category 2: > 4 years of age)

Dip-tank	Number of Dams	Age Category	
		1	2
1	48	11 (22.9%)	37 (77.1%)
2	24	5 (20.8%)	19 (79.2%)
3	25	7 (28.0%)	18 (72.0%)
4	34	4 (11.8%)	30 (88.2%)
5	26	6 (23.1%)	20 (76.9%)
Total	157	33 (21.0%)	124 (79.0%)

Table 4.6: Frequency distribution of cow parity at different dip-tanks in sample of 157 studied dams

Dip- tank	Parity								
	1	2	3	4	5	6	7	8	NE
1	8	12	4	6	1	2			15

	2	6	4	4	1	1		8		
	3	4	4	3		1	2	11		
	4	6	2	6	3	1	5	11		
	5	2	3	4	3		1	13		
Total		26	25	21	13	3	8	1	2	58

NE~ not evaluated

Table 4.7: Tick attachment scores (TAS) and distribution of dams assessed at different dip-tanks in the Mnisi community

Dip-tank (n=157)	TAS			
	0	1	2	3
1	0 (0%)	35 (72.9%)	11 (22.9%)	2 (4.2%)
2	0 (0%)	15 (62.5%)	9 (37.5%)	0 (0%)
3	1 (4.0%)	14 (56.0%)	8 (32.0%)	2 (8.0%)
4	2 (5.9%)	19 (55.9%)	12 (35.3%)	1 (2.9%)
5	0 (0%)	14 (53.9%)	12 (46.2%)	0 (0%)
Total	3 (1.9%)	97 (61.8%)	52 (33.1%)	5 (3.2%)

TAS~ tick attachment score

Table 4.8: Cow udder scores (CUS) and distribution of dams assessed at different dip-tanks in the Mnisi community

Dip-tank (n=157)	CUS			
	0	1	2	3
1	9 (18.8%)	12 (25.0%)	13 (27.1%)	14 (29.2%)
2	7 (29.2%)	7 (29.2%)	7 (29.2%)	3 (12.5%)
3	4 (16.0%)	5 (20.0%)	4 (16.0%)	12 (48.0%)
4	9 (26.5%)	13 (38.2%)	7 (20.6%)	5 (14.7%)
5	8 (30.8%)	10 (38.5%)	4 (15.4%)	4 (15.4%)
Total	37 (23.6%)	47 (29.9%)	35 (22.3%)	38 (24.2%)

CUS~ cow udder score

CUS 0 ~ no damage

CUS ~1 low damage

CUS ~ 2 moderately damaged

CUS ~ 3 highly damaged

4.2.3. Description of calf population

Figure 4.2 shows that out of the 157 calves enrolled within two weeks of birth, 114 (73%) reached weaning weight, 24 (15%) died, and 19 (12%) dropped out of the study for various reasons. Of the calves reaching weaning weight, 20 (18%) were too heavy to be weighed on the salter gauge and instead their heart girths, shoulder height and length were measured till they were weaned.

Similar to the cow breed types, there were also two calf breed types namely Brahman-type calves and Sanga-type calves, 117 (75%) and 40 (25%) respectively. Table 4.9 shows the breakdown of calves by breed-type and sex. More female calves were enrolled than males (57% females vs. 43% males).

Table 4.9: Representation of calves according to breed-type and sex

Calf breed-type	Calf sex	
	F	M
Brahman	71	46
Sanga	18	22

F~ female

M~ male

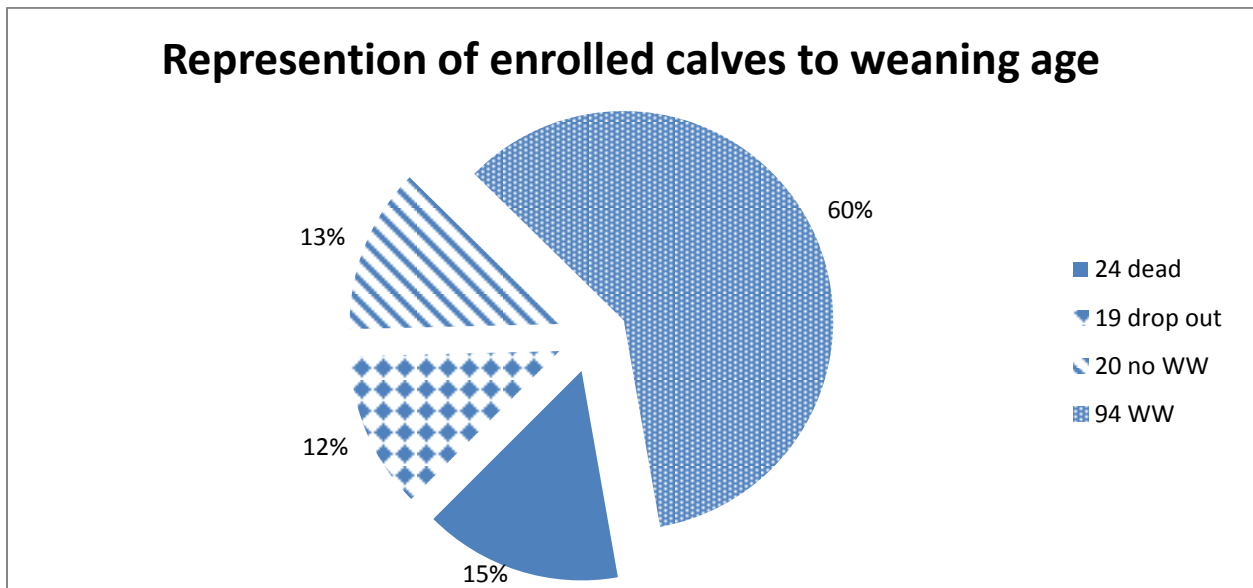


Figure 4.3: Distribution of enrolled calves in study

Figure 4.4. is a representation of the survival curve of calves over their eight month period in the study until their weaning age. At enrolment (month=0), calve population was 100%. Fifteen percent of the total enrolled calves died before reaching weaning age (month=8).

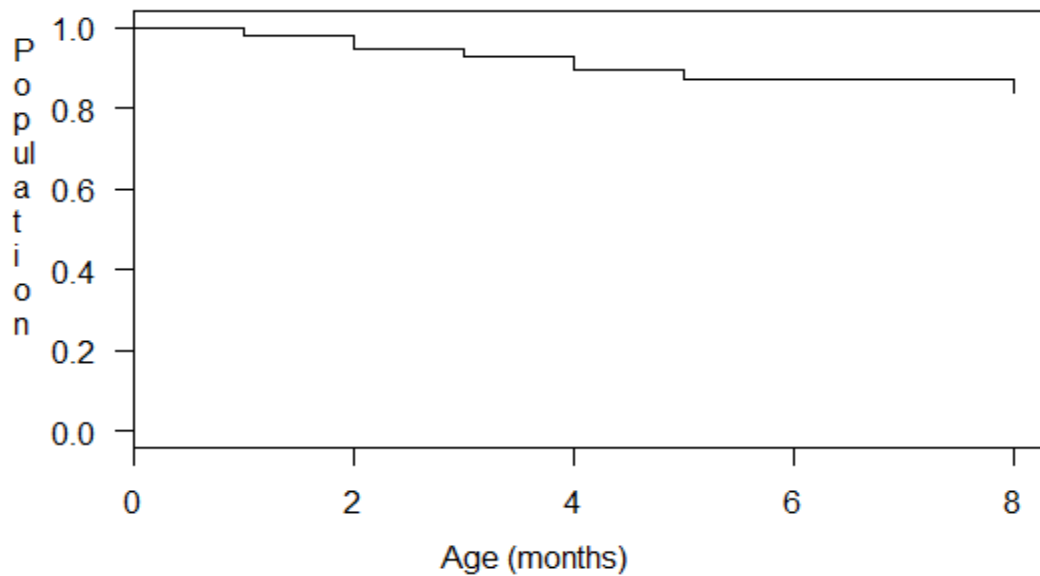


Figure 4.4 Survival curve for calves enrolled with two weeks of birth (n = 157)

4.3. ANALYSES

4.3.1. Association of CUS and TAS with ADG (Linear regression)

Table 4.10: Univariate Linear regression of ADG

Variable	Categories	ADG		Regression		
		mean	SD	Estimate	Wald p-value	LR p-value
Tick attachment	0*	0.34	0.06	-	-	0.9
	1	0.31	0.09	-0.03	0.6	
	2	0.32	0.09	-0.02	0.8	
	3	0.33	0.04	-0.01	0.9	
CUS	0*	0.32	0.1	-	-	0.5

	1	0.31	0.09	-0.01	0.6
	2	0.3	0.1	-0.03	0.3
	3	0.34	0.09	0.01	0.6

*Reference TAC

*Reference CUS

N~ number of calves

CUS~ cow udder score

CUS 0 ~ no damage

CUS ~1 low damage

CUS ~ 2 moderately damaged

CUS ~ 3 highly damaged

TAS 0 ~ no infestation

TAS ~1 low infestation

TAS ~ 2 moderately infested

TAS ~ 3 heavily infested

ADG~ average daily gain

SD~ standard deviation

LR~ linear regression

4.3.2. Factors associated with dam CUS and TAS (ordinal regression)

The results of the ordinal regression analyses to determine factors associated with dam TAS and CUS are presented in Tables 4.11 and 4.12, respectively. No factors were significantly associated with TAS, while dip-tank and parity were marginally associated with CUS. Dams from dip-tank 5 and their udder score damage (CUS) had a significant association ($P=0.05$). Dams at dip-tanks 2 and 4 had P -values of 0.1 and 0.08, respectively. This indicated the tendency of significant association between their CUS scores and environment (dip-tank). Dam parity and CUS score expressed a tendency of association ($P=0.08$).

Table 4.11: Ordinal regression table showing the association between dam factors and tick attachment scores (TAS)

Dam	Odds	95% confidence	P-value
-----	------	----------------	---------

description factors		ratio	Intervals		
			Lower	upper	
	1*	-	-	-	-
Dip-tank	2	1.42	0.52	3.84	0.5
	3	1.61	0.58	4.42	0.4
	4	1.32	0.52	3.31	0.6
	5	1.94	0.75	5.06	0.2
Age category	≤4*	-	-	-	-
	>4	1.15	0.54	2.55	0.7
Parity		1.1	0.86	1.39	0.4
BCS		0.7	0.43	1.11	0.1
HG		1	0.97	1.03	1
Breed-type	Brahman	-	-	-	-
	Sanga	0.78	0.41	1.48	0.4

*Reference dip-tank

*Reference age category

*Reference breed-type

BCS~ body condition score

HG~ heart girth

Table 4.12: Ordinal regression table showing association between dam factors and cow udder scores (CUS)

Dam description factors		Odds ratio	95% confidence intervals		P-value
			lower	upper	
	1*	-	-	-	-
Dip-tank	2	0.51	0.21	1.22	0.1
	3	1.78	0.82	4.5	0.22
	4	0.49	0.22	1.1	0.08
	5	0.42	0.18	1	0.05
Age category	≤ 4*	-	-	-	-
	> 4	0.85	0.43	1.7	0.6
Parity		1.21	0.98	1.5	0.08

BCS	1.02	0.67	1.54	0.9
HG	1.02	1	1.04	0.1

*Reference dip-tank

*Reference age category

BCS~ body condition score

HG~ heart girth

4.3.3. Factors associated with calf average daily gain, (linear regression)

The results of the linear regression analyses to determine dam and calf factors associated with calf average daily gain (ADG) are presented in Tables 4.13 and 4.14, respectively. Dam tick attachment score (TAS) and cow udder score (CUS) were not associated with calf ADG (Table 4.13, Figure 4.4 and Figure 4.5). Of the dam factors, only dip-tank was associated with calf ADG, with calves at dip-tank 4 having a significantly lower ADG (Table 4.13 and Figure 4.6).

Table 4.13: Univariate linear regression results for dam variables and their association with average daily gain (ADG) of calves

Variable	Categories	N	ADG		Regression		
			mean	SD	Estimate	Wald P-value	LR P-value
TAS	0*	2	0.34	0.06	-	-	0.9
	1	58	0.31	0.09	-0.03	0.6	
	2	32	0.32	0.09	-0.02	0.8	
	3	2	0.33	0.04	-0.01	0.9	
CUS	0*	24	0.32	0.1	-	-	0.5
	1	26	0.31	0.09	-0.01	0.6	
	2	22	0.3	0.1	-0.03	0.3	
	3	22	0.34	0.09	0.01	0.6	
Dip-tank	1*	28	0.33	0.1	-	-	0.04
	2	20	0.35	0.06	0.02	0.5	

	3	18	0.3	0.08	-0.02	0.4	
	4	17	0.26	0.09	-0.07	0.02	
	5	11	0.34	0.11	0.009	0.7	
Age	≤ 4*	21	0.34	0.09	-	-	0.1
category	> 4	73	0.31	0.09	-0.038	0.1	
Parity		57			-0.003	0.6	0.6
	3*	6	0.33	0.06	-	-	
BCS	4	40	0.31	0.1	-0.03	0.5	0.7
	5	45	0.32	0.09	-0.02	0.7	
	6	3	0.37	0.06	0.04	0.6	
HG		94			0.001	0.2	0.2
Breed-	Brahman*	53	0.32	0.1	-	-	0.3
type	Sanga	41	0.3	0.08	-0.02	0.3	

*Reference TAS

TAS 0 ~ no infestation

TAS ~1 low infestation

TAS ~ 2 moderately infested

TAS ~ 3 heavily infested

*Reference CUS

CUS~ cow udder score

CUS 0 ~ no damage

CUS ~1 low damage

CUS ~ 2 moderately damaged

CUS ~ 3 highly damaged

*Reference dip-tank

*Reference age category

*Reference BCS

*Reference breed-type

TAS~ tick attachment score

BCS~ body condition score

CUS~ cow udder score

HG~ heart girth

SD~ standard deviation

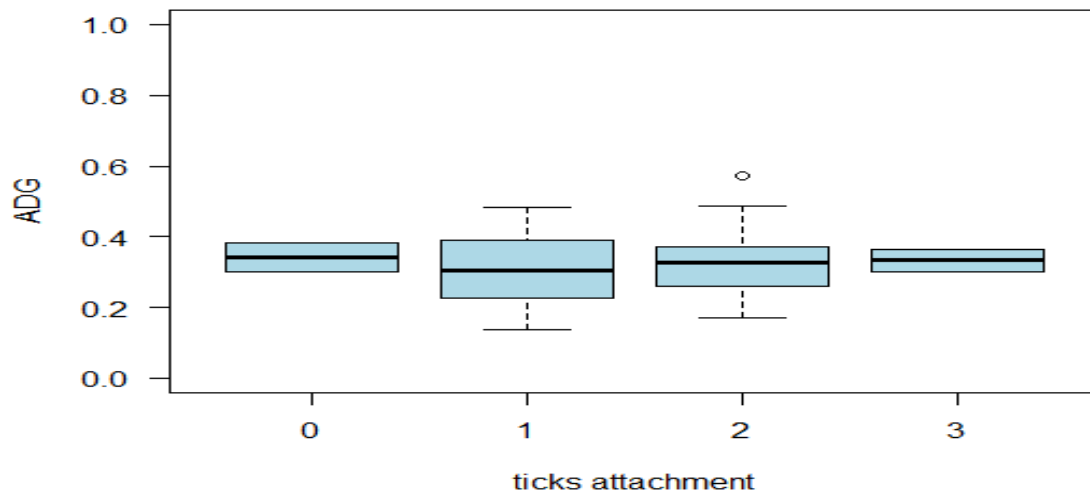


Figure 4.5: Average daily gains of calves from dams with different tick infestation levels udders

Figure 4.5 and Table 4.13 show that the average daily gains (ADG) of calves from dams with an increasing number of ticks on their udders, showed more variation and with numerically more calves adversely affected, e.g. standard deviations increased from 0.06 in cows with 0 tick attachment score, to 0.09 in cows with 1 or 2 TAS.

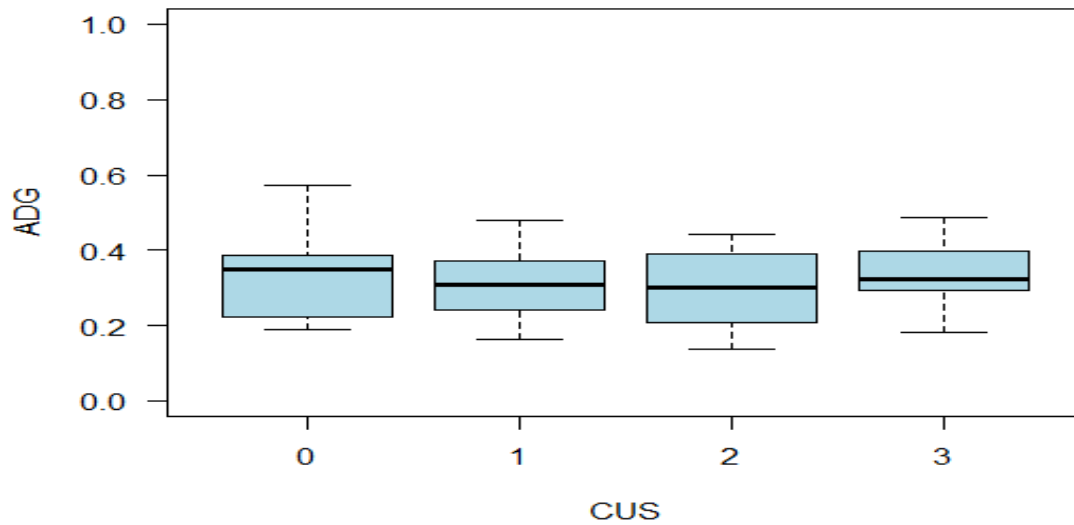


Figure 4.6: Distribution of calf ADG at different CUS scores

Figure 4.5 and Table 4.13 show that the average daily gains (ADG) of calves from dams with no or less udder damage (CUS), showed more variation and with numerically more calves adversely affected than calves from dams with highly damaged udders. The standard deviation for less damaged to more damaged udders did not show any link to the calves average daily gains (e.g. calves with CUS of 0 and 2 had SD of 0.1, compared to calves with CUS of 1 and 3 had SD of 0.09).

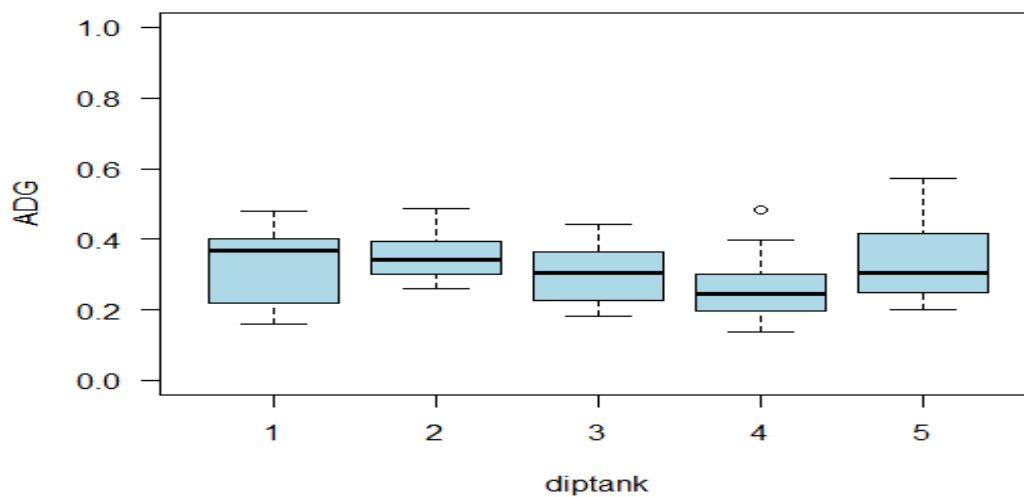


Figure 4.7: Distribution of calf ADG at different dip-tanks

In Figure 4.6, the median ADG of calves differed between dip-tanks. Calf average daily growth at dip-tank 3 is significantly different from calves at dip-tank 1, with calf growth at dip-tank 3 having a lower ADG.

Table 4.14 reveals the relationship of calf factors on their average daily gain(ADG). Birth month had a tendency of significant association with calf ADG ($P<0.1$), and calf initial weight ($P<0.05$) was significantly associated with calf ADG. Calves born in October, January and February had significantly lower ADGs than calves born in September. Calves with lower initial weights had significantly lower ADG and this could be an attribute by dam's poor CUS score.

Table 4.14: Univariate linear regression results for calf variables and their association with calf ADG

Variable	Categories	N	ADG		Regression		
			mean	SD	Estimate	Wald P-value	LR P-value
Birth month	August	5	0.28	0.09	-0.05	0.09	0.08
	September*	22	0.36	0.09	0	-	
	October	22	0.33	0.08	-0.1	0.03	
	November	21	0.29	0.09	-0.08	0.07	
	December	7	0.28	0.11	-0.03	0.3	
	January	13	0.31	0.09	-0.07	0.01	
	February	4	0.26	0.08	-0.08	0.05	
weaning month	March*	11	0.31	0.11	0		0.7
	April	24	0.34	0.13	0.03		
	Mai	15	0.31	0.09	-0.003		
	June	21	0.29	0.09	-0.02		
	July	10	0.3	0.09	-0.01		
	August	13	0.29	0.09	-0.02		
Sex	Female*	50	0.33	0.09	-	-	0.2
	Male	44	0.3	0.09	-0.02	0.2	
Breed-type	Brahman*	71	0.32	0.09	-	-	0.6
	Sanga	23	0.31	0.09	-0.01	0.6	
Calf initial weight		94			-0.005	0.002	0.002

Reference birth month

*Reference weaning month

*Reference sex

*Reference breed-type

N~ number of calves

ADG~ average daily gain

SD~ standard deviation

LR~ linear regression

4.3.4. Factors associated with calf survival

4.3.4.1. Association of CUS and TAS with calf survival (survival analysis)

Results of the survival analysis are presented in Table 4.15. There was no statistically significant association between calf survival and any of the variables evaluated.

Table 4.15: Table representing relationship in calf survival with dependent variables

		Coefficient	Exponential (coefficient)	Significance (P-value)
	TAS	-0.11	0.89	0.8
	CUS	0.27	1.31	0.1
	1*	-	-	-
Dip- tank	2	-0.01	0.99	1
	3	-1.73	0.18	0.1
	4	-0.28	0.76	0.6
	5	-0.32	0.73	0.6
	August*	-	-	-
Initial weight	September	-0.9	0.4	0.2
	October	-0.2	0.8	0.8
	November	-1.4	0.3	0.1
	December	-19	<0.0001	1
	January	0.2	1.2	0.8
	February	-19	<0.0001	1
	Female*	-	-	-
Sex	Male	-0.27	0.76	0.5

*Reference dip-tank

*Reference initial weight

*Reference sex

TAS~ tick attachment score

CUS~ cow udder damage score

5. DISCUSSION

5.1. CROSS SECTIONAL STUDY

5.1.2. Cow udder examination results

A total of 192 cows at ward B2 were examined over a period of 5 days (Monday to Friday) to examine and formulate a cow scoring system to be used for the cohort study at ward B1. The extent of damage on the udders was evaluated by palpating the udder and inspecting for the presence of nodules, warts, lesions, oedema, atrophy, fibrosis on each teat and on each quarter. The symmetry of each udder was also evaluated. It was found that on average 86% of evaluated cows had no damage to their teats or quarters, with the median for cows with no udder damage being at 176 cows. Even though the current study did not evaluate mastitis per se, but udder damage in cattle, the findings are in agreement with those reported in cattle with mastitis in other studies (Katsande et al., 2013). The latter study found that 4.8% of the cattle herd they investigated had a prevalence of mastitis. In the present study it was found that 6.5% of cows had udder damage (Table 4.1).

5.1.3. Relationship between cow udder score (CUS) and tick attachment score (TAS)

The cow udder palpation scores were evaluated to compile a cow udder scoring system (CUS), (Refer to 3.3.1.3.). The cow udder score (CUS) distributions for cows were numerically similar, with cows with CUS of 1 being more populated than the rest of the herd (30.21%). The mean tick attachment score (TAS) of cows was presented in Table 4.2. More of the cows had TAS of 1 (approximately 64%). The findings show that even though cows had no tick attachment on udders, there was still some prevalence of udder damage (TAS of 0 vs. CUS of 0).

5.1.4. Relationship between cow body condition score (BCS) and cow udder score (CUS)

Cow body condition score (BCS) and Cow body condition scores (BCS) and their udder scores (CUS) presented in Table 4.3 were evaluated. With score 1 representing very thin cows and score 9 representing obese cows, it was found that 80% of cows had BCS falling between categories 4 and 5 probably because this evaluation was done in July, during the dry season. The grazing veld was of poor condition at that time of year and cattle do not have enough fodder available. In the dry season the nutrient intake was lowered and thus cattle are seldom over conditioned. Farmers in the village generally keep a variety of cow breed types with different physiological constitutions. There has been studies done previously on beef cattle using the 1-9 score system and a mixture of cattle breeds using both the 1-9 scoring system and 1-5 score system (Nicoll, 1919; Morris et al., 1985; Reardon et al., 1987; Gilmour, 1998; Smeaton et al., 2000). These cows had an ideal condition as they had an overall good appearance. The hip bones were visible with little fat over the hocks and pins. Some cows with BCS 5 were fleshier than the cows of BCS 4, with their rib cages not being as clearly visible as those of BCS 4. They had some fat around the tail and brisket. In Table 4.3, it was found that

31% of cows had CUS of 1 with little udder damage, compared to 21% of the cows which had grossly damaged udders of CUS 4. Twenty four percent of cows in the cohort study had no visible udder damage (CUS=0). It was uncertain why there were cows with no apparent udder damage, but because cattle are frequently dipped by the animal health technician (AHT) services provided by the Mpumalanga Veterinary Services, these cows could either be of farmers who regularly brought their cattle to the dip-tank on a weekly basis for dipping and veterinary inspections or the cow udders were well cared for by the owners or herdsmen.

5.2. COHORT STUDY

5.2.1 Description of study population

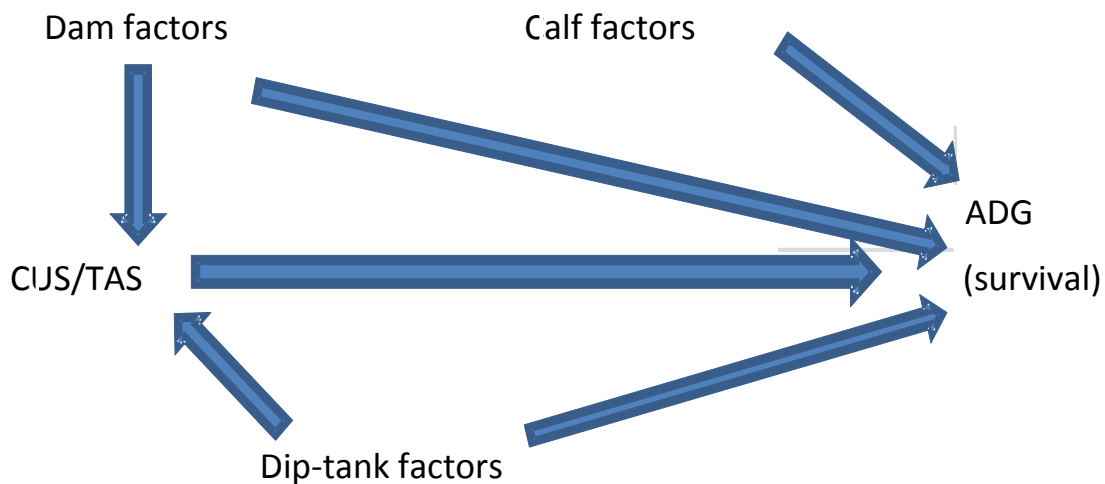


Figure 5.1 Causal diagram for regression model showing variables influences on calve ADG and survival rate

A causal diagram was used to show the assumed relationship link to estimating the relationship between dependent and independent variables on calf ADG. Cow factors being the dam breed-type, level of tick infestation on udders, parity, dam age category, heart girth (HG) measurement and body condition score (BCS). These were evaluated to measure the level of influence they have on calf daily growth (ADG). The level of tick infestation has an influence on dam udder scores (CUS) and this in turn has an influence on calf average daily gain (ADG). The calf factors evaluated are calf breed-type, sex, initial birth weight, month of birth, month of weaning and weaning weights. Dip tank factors are the 5 dip-tanks.

$$\ln \frac{F_{ij}}{1-F_{ij}} = B_{0j} + B_1X_1 + B_2X_2 + \dots + B_kX_k$$

5.2.2. Description of dam population

A total of 157 dams were evaluated at the study area, with a similar distribution of breed-type at the 5 dip-tanks (Table 4.5), with 50 percent of each breed-type well represented in the study. The dam distribution at each dip-tank varies, with dip-tank 1 having the highest number of dams enrolled, with 30.5% of total dam number. Fifty-eight percent of the dams from dip-tank 1 were Brahman-type and 42% were of Sanga-type.

5.2.2.1. Dam age

Age of dams was categorized into two categories, whereby all dams aged four years or younger (≤ 4 years) were of age category-1 and all dams older than four years (>4 years) were of age category-2. Table 4.5 reveals that 21% of dams were four years old or younger and 79% of dams were older than four years of age. Farmers keep their cattle for a long time before selling or slaughtering because of many factors. Because the study area was in a FMD-zone area, bordering the Manyeleti and Kruger National Park which are FMD zones because of the buffalo in the park and reserve, farmers are unable to sell their cattle making market accessibility very restricted and limited. Contact between buffalo and cattle was responsible for most of the FMD outbreaks in cattle at the edge of protected areas, which generate huge economic losses (Jori, & Etter, 2016). But there are other reasons why farmers keep cattle into their old age. Farmers keep animals that are well adapted to this particular environmental conditions, these cattle in the communal areas allow the farmer to not only have a source of income but also have draught power, manure and other socio-economic activities to cater for their day to day needs (Mapiye et al., 2009; Nqeno et al., 2011).

5.2.2.2. Dam parity

Dam parity was evaluated (Table 4.6). Of the dams examined, 37% of the parities were not recorded. The reasons for these omissions are due to poor recordkeeping by farmers and because some herdsmen who cared for the cattle could not get the information from the owners, who could not be reached. Thirteen percent, 16% and 13% of sampled dams had three, two and one accounts of parities, respectively, and the rest (17%) had parities of 4 or more. Parity was linked to maternal age. The older the cow the longer the calving intervals (Doren, 1985). Not all dams that calved had calves every year consecutively. Because of the

environmental challenges in the area, poor veld conditions and not all farmers were able to buy supplementary feed sources during the dry seasons, this influenced the quality of nutritional intake of cattle. Research has shown that for each 10% of body weight lost before calving, the dam has a delayed first heat period by 19 additional days. Cows too thin at calving take longer to recover and to start cycling for rebreeding. These cows will have lower conception rates than cows in moderate-to-good condition at calving (Weddle-Schott, L., 2012). As indicated in Table 4.6, parity was linked to maternal age, therefore the older the dam, the fewer the number of calves it will have.

5.2.2.3. Dam udder tick infestation and CUS

Dams with the highest level of tick infestations (TAS) had TAS-1 and TAS-2 scores, at 62% and 33% of dams, respectively (Figure 4.4). Five percent of dams in the study either had no ticks on udders or were highly infested with ticks on their udders. Prevalence of tick-infested cattle was found to be significantly higher on communal land (93.8%) and recently claimed land (85.1%) than on commercial farms (Ndhlovu, et al., 2009). There was a similar distribution of calves at each dam's CUS score. Thirty percent of dams had udder damage scores (CUS) of 1. And the rest had CUS-0 (24%), CUS-2 (22%) and CUS-4 (24%).

Ndhlovu (2009) found that the percentage of tick-infested animals with udder damage was higher than those with tick infestation but with no udder damage. In this study it was found that 98% of dams were infested with ticks on their udders but there was no correlation with the number of animals with udder damage (76%). Ndhlovu (2009) also found that the percentage of tick-infested animals with teat damage was higher than those with tick infestation but with no teat damage. In this study, there was no correlation shown with the level of tick infestation and the level of udder damage (Table 4.7). These findings can be attributed by the frequent dipping of cattle at the dip-tanks. Reducing the tick infestation load but not having any influence on the damage already done by ticks on udder quarters and teats.

5.2.3. Description of calf population

The breed types of the progeny was not necessarily similar to that of the dams due to crossbreeding in the Mnisi community. There were humpless cattle in the Mnisi area. Some are Nguni cattle from the Zululand (Brown, 1959) and the Pedi cattle from the Northern Transvaal. There are traces of Sanga breeds from Zimbabwe and Zambia known as Nkones and Tuli breeds. Collectively all these breeds are referred to as Sanga-types. These cattle are smaller in frame making them easier to manage and handle. It was generally accepted that the reproductive rates of indigenous livestock breeds are extremely low. But in their reviews,

Maule (1973) and Heyzel (1988) reported average calving percentages of between 64% and 91% and 68% and 87%, respectively in various herds of Sanga cattle in Southern Africa. In a beef industry dominated by *Bos taurus* breeds, Brahman (*Bos indicus*) have gained a unique place because of their environmental adaptation and attributes in crossbreeding (Frank, 1980; Turner, 1980).

One would expect that because 157 dams were enrolled, with 50.32% Brahman-type and 49.68% Sanga-type dams, the calf ratios would be similar. But according to Table 4.7 it shows that the calves born are not necessarily of the same breed types as their dams. Because of crossbreeding activity among the communal farmers and preference of using BR- type bulls in their herds to improve the herd quality in the sense that they would calve larger framed calves and meat value, adding rand per kg. There are 74.52% Brahman-type calves, 24.2% more Brahman-types in the F₂ generation than the F₁ and there are 24.4% less Sanga-type calves in the F₂ generation than the F₁ generation. This was a reflection of the farmers' preference of *Bos indicus* bulls in their herds.

Figure 4.2 presents calf population from enrollment till weaning. Sixty percent of the enrolled calves reached weaning month, 15% died early in the study at 3 months of age or earlier. Thirteen percent of the calves were too heavy to be weighed at weaning using the block and tackle method with the salter gauge. Instead the calves' heart girths (HG), shoulder heights and lengths were measured in efforts to estimate their weight at weaning month. Twelve percent of total enrolled calves dropped out of the study and did not complete the study till weaning age for different reasons. Some farmers were reluctant to continue the study and therefore pulled their calves out of the study, while some calves went missing or stolen during the study duration and were never found again. Represented in Figure 4.3, as expected, the calf survival population was 100% at enrollment because all calves studied were alive. But it was shown in the graph (Figure 4.3), over time, some calves were dying resulting in 85% of calves reaching weaning age. This can be attributed to many reasons. Wymann, (2006) found that causes of calf mortality was because of digestive tract disorders (28%) and accidents (14%). Vector-borne and infectious diseases were of low importance, and this could be because of the type of breed of calves in the area, making them hardy and immune to many diseases. But it was also found that starvation could be another factor contributing to a high level of deaths in communal areas. The high level of calf mortalities may be caused by a dysfunctional dam, meaning that the dam was unable to feed it's calf primarily because teats are clogged or the udder was dead or both. Therefore resulting in the calf being unable to suckle the colostrum in its initial time of birth and milk from its mother (Dube, 2015).

5.3. ANALYSES

5.3.1. Association of CUS and TAC with ADG (Linear regression)

Regression models are used to maximize the amount of information we could get for the possibility of any significant relationship between cow udder scores (CUS) and/or tick infestation levels (TAS) and independent categorical variables, in this case, looking at the association of TAS and CUS on calf average daily growth (ADG).

$$\log(\pi_j) = \ln\left(\frac{\pi_j}{1-\pi_j}\right) = \alpha_j + \beta^T x$$

5.3.1.1. Tick attachment on dam udders and calf ADG

It would be expected for calves suckling on highly infested udders to grow slower and gain less weight compared to calves suckling on less infested udders. Instead in this study calves suckling on differently tick infested udders gained numerically similar weights (Table 4.10). A study conducted by Pegram (1989), found infestations of 50–120 adult *Amblyomma variegatum Fabricius* in untreated cattle, cause a significant reductions in live weight gain (LWG) of calves. From the differences in LWG between treated and untreated cattle, the induced loss in LWG was estimated at 46–61g per engorged female *A. variegatum*. This meant that dams with suckling calves, when infested with ticks all over their bodies, they would be prone to production challenges. But not necessarily if the udders are infested or not. Represented in Table 4.10, there was no significant relationship between tick infestation on dam udder (TAS) and calf average gain ($P > 0.05$). This was in agreement with literature stating that tick attachment on dam udders caused no significant reduction in milk yield or calf growth over the whole period of a study conducted by Norval (1997).

5.3.1.2. Dam CUS and calf ADG

Calves suckling on CUS-0, CUS-1 and CUS-2 had mean average daily gains (ADG) of 320g, 310g and 300g. With exception of CUS-3 (mean ADG = 340 g), the calves gained less weight as the CUS worsened. This was in agreement with Norval (1997) who concluded that milk production was not an important consideration when estimating the losses in production and calve growth and development caused by ticks on Brahman x Sanga or Sanga breeds. Losses were caused by the degree of teat or udder damage. Calves suckling on dams with CUS=3 have the highest mean ADG. Norval (1997) stated that calf growth would be normal provided that the teats of the dams had not been damaged by ticks and that the dams would only exhibit mis-mothering

behavior when teats were damaged. The gaining of weight of calves of CUS=3 can be assumed to be because udders of dams could have had parenchyma damage but the teat opening and teat canals were not damaged, thus not causing obstruction for milk let-down. As presented in Table 4.10, there was no associated relationship between calf ADG and CUS score ($P>0.05$). Calves continued to gain weight even with different levels of udder damage (CUS). The extent of CUS does not affect the dam's ability to synthesize and produce milk for calve.

5.3.2. Factors associated with dam CUS and TAC (ordinal regression)

5.3.2.1. Influence of Dam factors on TAC

Tables 4.11 and 4.12 are ordinal regression tables representing the association of dam factors with level of tick infestation on udders (TAS) and cow udder score (CUS), respectively. The degree of tick attachment thus infestation on the dam udder was not significantly influenced by the dam factors (dip-tank, age category, parity, BCS, HG and/or breed type) examined in the study ($P>0.05$). But there was a tendency towards significance between dam BCS and tick infestation level (TAS), $P=0.1$. The more ticks attached to the dam udders, this will affect the dam's BCS because they are blood sucking. In large numbers they cause reduction of cattle live weight and anemia (Rajput, 2006) The dam loses condition. In a study by Mamoudou (2015), whereby he investigated the impact of tick infestation and trypanosomiasis in cattle in Cameroon, he found that the BCS score was poor for the majority of the cattle sampled, even though the frequency of cattle with a poor BCS differed significantly according to cattle health status.

5.3.2.2. Influence of Dam factors on CUS

The association of dam factors on the prevalence of cow udder score (CUS), was represented in Table 4.12. There was no significant association for some of the dam factors (age category, parity, BCS, HG and/or breed type) and the degree of CUS score on dams ($P>0.05$). Dip-tank 5 had a statistically significant association with dam CUS score ($P=0.05$), and dip-tanks 2 and 4 showing a tendency towards significant association to dam CUS, with P -values of 0.1 and 0.08, respectively. Cattle are grouped according to their geographical locations and are monitored at central dip tanks (dip-tank 1, 2, 3, 4 and 5). The grazing area at the dip-tanks was not maintained, therefore there was a high possibility of udders being damaged due to a variety of environmental factors such as the weather (sunburn and frostbite) or by direct damage caused by tick bites, grass and thorns, mud and other elements (Hillerton, 2003). Dam HG was measured in the study at calve initial weights. The relationship between initial HG and CUS score was tending towards a significant relationship, $P=0.1$. Dam's HG was influenced by many

factors such as weight, BCS and tick infestation on dam's body and udders. The more damaged the udder was because of other factors but also secondary effects by tick attachment, than there was a high-linked probability of the dam's body also being infested by ticks and having secondary health effects.

5.3.3. Factors associated with calf ADG (linear regression)

5.3.3.1. Dip tank influence on calve ADG

South Africa is characterized by frequent variation in its natural resources e.g. quality and quantity of grazing and water due to seasonal variation, sporadic droughts, veld fires, pressure on agricultural land and land claims (Webb, 2016). The fact that cattle in the smallholder areas largely rely on natural pastures, whose quality, particularly crude protein content, decline during dry season leads to losses in animal body weight and condition (Ainslie, 2002).

There was a statistically significant association between dip-tank and calf ADG ($P= 0.04$),(Table 4.13). Generally calf distribution at the dip-tanks is similar with exception to dip tank 1 and 5 having the most and least calves enrolled till weaning, respectively. The calf mean ADG numerically differs amongst the dip-tanks. Calves at dip-tank 4 had the lowest ADG (260g), calves from dip-tanks 1, 2 and 5 had numerically similar ADG (330g, 350g and 340g). Location of dip-tanks could have an influence on the dam's nutritional health during gestation and lactation, considering the vegetation integrity of the areas at the dip-tanks. The smallholder cattle herds are dominated by nondescript crossbreds between indigenous and imported breeds. These crossbreds have high nutritional requirements (Mapiye, 2011). Milk quality describes the percentage of nutrients and somatic cell counts in milk. Milk from Holstein-Friesian cows contains approximately 4.9% lactose and 3.4% protein (Flynn & Casman, 1997). No information is available on milk quality of Nguni and crossbred cattle (Mapekula, 2009). Milk is the sole source of these nutrients for the calf during its first few months until it depends on feeding off forage material. Milk provides the calf with an immunity system helping it to resist against infectious diseases (McDonald, 1995). Water has the most dramatic effect on milk yield reduction (McDonald, 1995; 2002). The communal farmers practice farming in an environment which was water and nutrient restricted (Mapekula, 2009), especially during the dry winter seasons, affecting pasture quality. Pastures rich in nutrients such as protein and energy become very limited during these dry periods. Communal farmers lack funds to buy supplementary feeds (Hazel, 2008) and lack the knowledge of cultivating pastures that use less water. Figure 4.6, a box-plot diagram show the distribution of calf ADG against dip-tank (location). Most of the calves ADG was spread between 180-400g, with the medians being at a numerically similar ADG range, ca. 300g.

5.3.3.2. Dam age category and the influence it has on calf ADG

The relationship between the age of the dam and calf growth (ADG) is presented in Table 4.13. Dams four years old or younger (≤ 4 years) had calves with mean ADG heavier than for calves born from dams older than 4 years (>4 years). Literature states that both birth and weaning weights increased with advancing age of dam, reaching a peak in mature dams and declined when dams reached an old age (Raphaka & Dzama, 2009). Dam fertility is affected by their age, making it a major fertility factor for dams. After puberty, dam fertility increases and then decreases, with advanced maternal age causing a decrease in fertility and health. The effects of age of dam on birth weight and weaning weight were found to be curvilinear and concurred with well-established trends (Raphaka & Dzama, 2009). In their findings, they found that there was an increase in birth weight from three to six year old dams in the Tswana breeds and a peak was reached between dams aged between six and nine years of age, and decreasing with older dams. This was in agreement with our findings that calves suckling on dams which were 4 years old or younger were heavier and expressed a heavier ADG growth than for calves born from dams older than four years old. In this study, age groups are categorized into two groups, making it bias to fully account for calves born from heifers, dams which were young, dams at peak reproductive age and dams regarded as old (9+ years). There was a tendency towards a shared significant relationship between calf and dam age category ($P=0.1$), Table 4.13.. This is in agreement with findings by Elzo *et al.*(1987) , whereby older dams also had the ability to provide the foetus with the necessary nutrients and environmental conditions for its development and thus achieve good acceptable weights. The age of the dam is not to be a factor of consideration for calve ADG because both young and older dams possess different characteristics to grow calve of equally similar mean ADG till weaning weights.

5.3.3.3. Influence of calf initial weight on calf ADG

In the linear regression performed to test calf initial weight as a factor to its mean ADG, Table 4.14 shows that there was a significant link with calf initial weight and calf mean ADG ($P=0.002$). Fetal growth was indicated by birth weight and has important influence on the calf's production. Birth weights below the optimum are normally associated with reduced energy reserves. In addition to this, low birth weights are related to low rates of growth after birth and decreased mature size (Ferrell, 1993). Both the sire and dam contribute to the differences in genetic potential for growth , but it was evident that the dam exerts an influence beyond her contribution to fetal genotype even though it is argued that the cow's uterine environment limits fetal growth to a varying degree. Other factors such as maternal nutrition, environmental temperature and number of fetuses have an influence on fetal growth (Ferrel, 1993) therefore birth weight and weaning weight. In the present study farmers grazed their livestock on communal land. There are 157 calves enrolled in the study with 40 Sanga-type and 117

Brahman-type calves. Scholtz (2005) stated that a birth weight of 35kg for Nguni crosses with Belgium Blue bulls should be acceptable in the case of the Nguni. Nguni birth weight averaged at 27kg and the weaning weight averaged at 183kg (Scholtz, M.M., 2005). In this study's findings the mean birth weight for Sanga-type and Brahman-type calves is 29.2kg and 30.55kg, respectively.

5.3.3.4. Relationship of calf birth month and weaning month on calf ADG

In Table 4.14, calf birth month shows a tendency of a statistically associated relationship with calf mean average daily gain (ADG) at a significance value of $P=0.08$. One would assume that calves born in the wet season (October – February) would have heavier mean ADGs. It is not the case in the findings of the study because the mean ADG of calves born in the different months are numerically different with no similarity or correlation to months they are born in. The mean ADG of calves born in August (SD=0.09) is 80g lighter than of calves born in September (SD=0.09). And the mean ADG of calves born in October (SD=0.08) is 30g lighter than of calves born in the September month. Calves were weaned between 203-210 days of age. Birth weight determines how much milk the calf will consume (Rentfrow, 2004). Dip-tank areas, Welverdiend A and Welverdiend B, had very little vegetation available because of drought and farmers complained about water scarcity in the area. This could have been one of the contributing factors for lighter calf weight gains. Brahman-type calves are larger in frame compared to Sanga-type dams as they are smaller framed, putting pressure on nutrient demand for larger framed calf body growth and development. Generally the weaned calves have similar mean ADG and SD of 90g, with exception for calves weaned in in the April month with a mean ADG of 340g and SD of 130g. The relationship between weaning month and mean ADG was not statistically significant at $P> 0.05$.

5.3.4. Factors associated with calf survival

The variable, time to death, was evaluated against independent variables, to measure the risk they had on time of death. The cox proportional hazard model was used:

$$h(t) = h_0(t)e^{b_1X_1}$$

The model compared hazards of death for different independent variables. In table 4.15, the p-values for each variable was found to not be significant ($P>0.05$), therefore no risk factor associated with calving season.

6. CONCLUSION

6.1. Dam factors

In conclusion, there was no statistically significant association between tick infestation (TAC) on dam udders and cow factors (e.g. dip-tank, age category, parity, heart girth or breed type) except for dam body condition score. Dam parity and the dip-tank area had an influence on the extent of udder damage as assessed by cow udder scores (CUS). Dip-tank 4 and 5 had a significant relation to dam's CUS. Increasing parity e.g. cows that suckled more calves causes more udder damage over time, making it more susceptible to infections. Although dam breed type did not affect calf growth, BR-type dams were normally larger framed and heavier than the SR-type dams, and produced heavier calves with higher ADG than calves of SR-type dams. Dams were grouped into two age categories namely, dams four years or younger and dams older than four years. The dam's age had no influence on the levels of tick infestation or udder score, but affected growth rates (ADG) of calves. Literature indicates that dams between the ages of 4 to 6 years generally produce heaviest calves with highest ADG's. This could be attributed to the fact that dams younger than 4 years could have been heifers. Heifers are still young and developing cows, which explains why they generally produce smaller calves that grow slower.

6.2. Calf factors

Tick attachment on dam udders did not affect the growth of calves to weaning age. It was suspected that the secondary damage the ticks have on the udder's milk production and obstruction to milk let-down through the teats and teat canals would have a greater effect on calf growth to weaning age.

Although BR-type calves were heavier at birth and at weaning, as expected, because of their larger frame size compared to SR-type calves, it had no significant effect on ADG's of calves to weaning age. Bull calves were heavier than the heifers, which agrees with literature. The season of calf birth is linked to the season in which calves are weaned, which influenced the ADG's of calves. The availability and quality of rangeland depends on the season. The latter influenced the ability of dam to gain weight and thus accumulate energy for primary production but also secondary production which is milk availability for calf growth to weaning age. Calf growth is influenced by many factors but birth weight had a significant effect in this study. Calf birth weight provides an indication of how the calf will perform until it is weaned, and in particular the post-weaning performance of calves.

6.3. RECOMMENDATIONS

A host of confounding factors could influence the results, whereby it should have been excised due to caution in interpretation of results. As stated in the discussion that a cow reached its

peak reproductive activity between the ages of 4-6 years of age. The dams grouped in age category >4 years old are classified as older dams. But this is prejudice to the fact that the age classification was not specified according to age of reproduction, because this has an influence on the quality of calf born. CUS needs to be evaluated on the level of damaged caused on the udder itself but also the level of damage on the teat opening and canals because this is where the restriction of milk to calves during suckling would be identified, thus better evaluation on milk availability to calves for growth to weaning age. The dam's HG and BCS was only measured at enrolment of calves, at the calf initial weight soon after they birth. The HG and BCS of dam was not measured at calf weaning age. It would be better to evaluate the level of BCS and HG change at calf birth and at weaning age.

There is an urgency to helping farmers with alternative tick control strategies either than dipping at the dip-tanks because ticks have become immune to acaracides provided by the Mpumalanga State Veterinary Services. The Mnisi Tribal Authority also needs to formulate an agreement for the use of communal rangeland, allowing for sections of range land to be rested while others are utilized. This will help decrease tick population and spread. Youth must also be encouraged to participate more in agricultural projects in the area as they will play a vital role in the agricultural sector in the future.

7. LIST OF APPENDICES

7.1 Dam Evaluation Sheet

Date: _____

Researcher: _____

Environmental Monitor: _____

Tag ID										
Dip Tank	1	2	3	4	5					
Breed Type	BR				SR					
BCS	1	2	3	4	5	6	7	8	9	
HG (cm)										
Age Category(years)	≤ 4				≥ 5					
Parity Estimate										
Tick Attachment	0	1	2	3						

Keys:

- Dip Tank: 1= ClareB, 2=Clare A, 3=Welverdiend A, 4=Welverdiend B, 5= Thlavekisa
 Breed Type: BR=Brahman-type, SR=Sanga type
 BCS: 1 to 3= underweight, 4-6 fair, 7-9= overweight
 Tick Attachment: 0= no ticks, 1=slightly infested, 2= moderately infested, 3= heavily infested

7.2 Dam Udder Damage Evaluation Sheet

Udder and Teat Assessment Sheet

Teats																				
	LF	RF	LH	RH	LF	RF	LH	RH	LF	RF	LH	LR	LF	RF	LH	RH	LF	RF	LH	RH
Canal Nodules																				
Canal Opening																				
Warts																				
Lesions																				
Quarters																				
Warts																				
Lesions																				
Oedema																				
Atrophy																				
Fibrosis																				
Nodules																				
Whole udder																				
	Symmetrical										Non-symmetrical									
Comments																				

Keys: RF= right front quarter, RH= right hind quarter, LF= left front quarter, LH= left hind quarter

7.3 Calf Evaluation Sheet

Date: _____

Researcher: _____

Environmental Monitor: _____

Dam Tag ID									
Calf Tag ID									
Dip Tank	1	2	3	4	5				
Breed Type	BR		SR						
DOB									
Month of birth	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
Sex	F		M						
Weights (kg)	Initial	M1	M2	M3	M4	M5	M6		

Keys:

Dip Tank: 1= ClareB, 2=Clare A, 3=Welverdiend A, 4=Welverdiend B, 5=Thlavekisa
 Breed Type: BR=Brahman-type, SR=Sanga type
 Sex: F= female, M=male
 M1=month 1, M2=month2....M6=month6

8. REFERENCES

- Bayemi, P.H., Webb, E.C., 2009. An integrated method for improving the dairy production sector in developing countries: the case of Cameroon. *Trop Anim Health Prod.* 41:525–534.
- Bayou, E., Haile, A., Gizaw, S., Mekasha, Y. (2015). Evaluation of non-genetic factors affecting calf growth, reproductive performance and milk yield of traditionally managed Sheko cattle in southwest Ethiopia. *SpringerPlus*, 4:568.
- BIF, 2002. Guidelines for uniform beef improvement programs. Beef Improvement Federation (BIF), Georgia, USA.
- Cafe L. M., Hennessy D. W., Hearnshaw H., Morris S. G., Greenwood P. L. (2006). Influences of nutrition during pregnancy and lactation on birth weights and growth to weaning of calves sired by piedmontese or wagyu bulls. . *Australian Journal of Experimental Agriculture*, 46, 245-255.
- Cardellino, R. & Frahm, R.R.(1971). Evaluation of two types of age-of-dam correction factors for weaning weight in beef cattle. *J. Anim. Sci.* 32, 1078-1083.
- Carvalho, J.G., Blake, R.W., Pollak, E.J. & Van Soest, P.J.(1995). Comparison of Landim and Afrikaner cattle in Southern Mozambique: Body weights and growth. *J. Anim. Sci.* 73, 3519-3526.
- Cundiff, L.V., Willham, R.L. & Pratt, C.A.(1966). Effects of certain factors and their two-way interactions on weaning weight in beef cattle. *J. Anim. Sci.* 25, 972-982.
- Cunningham, E.P. & Henderson, C.R.(1965). Estimation of genetic and phenotypic parameters of weaning traits in beef cattle. *J. Anim. Sci.* 24, 182-187.
- de Castro, J.J., 1997. Sustainable tick and tick borne disease control in livestock improvement in developing countries. *Veterinary Parasitology.* 71: 77-97.
- Doren, P.E., Long, C.R., Cartwright, T.C.(1985). Factors affecting the Relationship Between Calving Interval of Cows and Weaning Weights of Calves. *J. Anim. Sci.* 6(5), 1194-1202.
- Dzama, K., Walter, J.P., Ruvuna, F. & Taylor, J.F., 1997. Growth characteristics and age of dam adjustment factors of purebred indigenous and exotic cattle in Zimbabwe. *Transactions of the Zimbabwe Scientific Association* 71, 5-8.
- Dube, M. (2015). Udder management critical in avoiding calf losses. *The Sunday News*

Elzo, M.A., Quaas, R.L. & Pollak, E.J., 1987. Effects of age-of-dam on weight traits in the Simmental population. *J. Anim. Sci.* 64, 992-1001.

Freetly, H. C., Ferrell, C. L., & Jenkins, T. G. (2000). Timing of realimentation of mature cows that were feed-restricted during pregnancy influences calf birth weights and growth rates. *J.Anim.Sci.*, 78(11), 790-2796.

Greenwood, P. L., & Cafe, L. M. (2007). Prenatal and pre-weaning growth and nutrition of cattle: Long-term consequences for beef production. *J.Anim. Sci.l*, 1(9), 1283-1296.
doi:10.1017/S175173110700050X

Hammon, H.M., Steinhoff-Wagner, J., Flor, J., Schönhusen, U., Metges, C.C., 2013. LACTATION BIOLOGY SYMPOSIUM: Role of colostrum and colostrum components on glucose metabolism in neonatal calves. *J. Anim. Sci.* 91:685-695.

Hillerton, J.E., mein, G.A., Neijenhuis, F., Reinemann, D.J., Baines, J. R., Ohnstad, I., Rasmussen, M.D., Timms, L., Britt, J.S., Farnsworth, R., Cook, N., Hemling, T., 2003. Evaluation of bovine teat condition in commercial dairy herds: Environmental factors. Proceedings of the 2nd International Symposium on Mastitis and Milk Quality. NMC/AABP, Vancouver, p374-351.

Ingvartsen, K. L., and J. B. Andersen. 2000. Integration of metabolism and intake regulation: a review focusing on periparturient animals. *J. Dairy Sci.* 83:1573-1597.

Jasper, J., Budzynska, M., 2008. Weaning distress in dairy calves: Acute behavioural responses by limit-fed calves. *J.Int.Society Appl.Ethology.* 110: 136–143.

Janice, M., Van Vleck, L.D. (2004). Age-of-dam adjustment factors for birth and weaning weight records of beef cattle: a review. *Online journal of Genetic and molecular research.* Jori, F., Etter, E., 2016. Transmission of foot and mouth disease at the wildlife/livestock interface of the Kruger National Park, South Africa: can the risk be mitigated? *Preventive Veterinary Medicine*, 126, 19-29.

Jeffrey, H.B., Berg, R.T. (1972). Influence of cow size and other factors on weight gain of beef calves to 365 days of age. *Can. J. Anim.Sci.*, 52:11-21.

Johnson, D.R., Lorenz, G., Studebaker, G., Hopkins, J. D., 2006. Livestock insect series: Ticks on beef cattle. University of Arkansas, Division of agriculture, cooperative extension services.. [web] <http://www.uaex.edu> [Accessed: 21 October 2013].

Katiyatiya, C.L.F., Muchenje, V., Mushunje, A., 2014. Farmers' Perceptions and Knowledge of Cattle Adaptation to Heat Stress and Tick Resistance in the Eastern Cape, South Africa. *Asian-Australas J.Anim.Sci.*, 27(11), 1663–1670.

Kars, A.A., Erasmus, G.J. & Van der Westhuizen, J., 1994. Factors influencing growth traits in the Nguni cattle stud at Bartlow Combine. *S. Afr. J. Anim. Sci.* 24, 18-21.

Katsande, S., Matope, G., Ndengu, M. & Pfukenyi, D.M., 2013. Prevalence of mastitis in dairy cows from smallholder farms in Zimbabwe. *Onderstepoort Journal of Veterinary Research*, 80(1), 523-560.

Knight, C. H., Peaker, M., 1982. Development of the mammary gland. *J. Reprod. Fert.* 65: 521-536.

Mahlobo, B.T. (2016). Multi-criteria livestock assessment for sustainability of smallholder farms in Kwa-Zulu Natal

Mamoudou, A., Suh, P. F. & Jean, E. N., 2015. Impact of Tick Infestation and Trypanosomiasis in Cattle in the Sudano-Sahelian Zone of Cameroon. *J Vet Adv.*,5(5): 919-924.

Mapholi, N. O., Maiwashe, A., Matika, O., Riggio, V., Banga, C., MacNeil, M.D., Muchenje, V., Nephawe, K., Dzama, K., 2017. Genetic parameters for tick counts across months for different tick species and anatomical locations in South African Nguni cattle. *Trop. Anim. Health Prod.* 49(6): 1201-1210.

Martey, E., Prince, M. E., Wiredu, A. N., Dogbe, W., 2014. Factors influencing willingness to participate in multi-stakeholder platform by smallholder farmers in Northern Ghana: implication for research and development. *Agriculture and Food Economics*. 2:11.

Mashishi, M.S.K., 2012. Udder and teat lesions-cattle. Department of Agriculture, fisheries and fisheries, Republic of South Africa. www.daff.gov.za/publications.

Melka, H.D., 2001. Genetic parameter estimates for weaning traits in a multibreed beef cattle population. MSc (Agric) thesis, University of Stellenbosch, Stellenbosch, South Africa.

Meltzer, M.I., 1996. A possible explanation of the apparent breed-related resistance in cattle to bont tick (*Amblyomma hebraeum*) infestations. *Veterinary Parasitology*. 67: 275-279.

Meltzer, M.I., Norval, R.A.I., 1993. Evaluating the economic damage threshold for bont tick (*Amblyomma hebraeum*) control in Zimbabwe. *Experimental & Applied Acarology* 17: 171-185.

Morrison D.G., Spitzer J.C., Perkins J.L., 1999. Influence of prepartum body condition score change on reproduction in multiparous beef cows calving in moderate body condition. *J Anim Sci.* 77(5):1048-54.

- Muchenje, V., Mhlanga, F.N. & Makuza, S.M., 1998. Adjusting lactation milk yield of Zimbabwean Holstein dairy cows for the joint effects of age at calving and month of calving. *J. Appl. Sci. Sthn Africa*. 4, 35-42.
- Ndhlovu, D.N., Makaya, P.V., Penzhorn, B.L., 2009. Tick infestation, and udder and teat damage in selected cattle herds of Matebeleland South, Zimbabwe. *Onderstepoort Journal of Veterinary Research*, 76, 235-248.
- Nelsen, T.C. & Kress, D.D., 1981. Additive and multiplicative correction factors for sex and age of dam in beef cattle weaning weight. *J. Anim. Sci.* 53, 1217-1224.
- Newman, S., McNeil, M.D., Reynolds, W.L., Knapp, B.W. & Urick, J.J., 1993. Fixed effects in the formation of a composite line of beef cattle: II. Pre and postweaning growth and carcass composition. *J. Anim. Sci.* 71, 2033-2039.
- Norval, R.A.I., Perry, B.D., Meltzer, M.I., Kruska, R.L., Booth, T.H., 1994. Factors affecting the distributions of the ticks *Amblyomma hebraeum* and *A. variegatum* in Zimbabwe: implications of reduced acaricide usage. *Experimental & Applied Acarology*, 18: 383-407.
- NORVAL, R. A. I., SUTHERST, R. W., JORGENSEN, O. G., & KERR, J. D. (1997). The effects of the bont tick, *Amblyomma hebraeum*, on milk production of sanga and sanga x brahman cattle. *Medical and Veterinary Entomology*, 11(2), 143-147.
- Paputungan, U., & Makarechian, M. (2000). The influence of dam weight, body condition and udder scores on calf birth weight and preweaning growth rates in beef cattle. *Asian Australasian Journal of Animal Sciences*, 13(4), 435-439.
- Pegram, R. G., Lemche, J., Chizyuka, H. G. B., Sutherst, R. W., Floyd, R. B., Kerr, J. D., et al. (1989). Effect of tick control on live weight gain of cattle in central Zambia. *Medical and Veterinary Entomology*, 3(3), 313-320.
- Perry, B.D., Randolph, T.F., 1999. Improving the assessment of the economic impact of parasitic diseases and of their control in production animals. *Veterinary Parasitology*. 84: 145–168.
- Perry, B.D., Young, A.S., 1995. The past and future roles of epidemiology and economics in the control of tick-borne diseases of livestock in Africa: the case of theileriosis. *Preventive Veterinary Medicine*. 25, 107-120.
- Phiri, B.J., Benschop, J., French, N., 2010. Systematic review of causes and factors associated with morbidity and mortality on smallholder dairy farms in Eastern and Southern Africa. *Preventive Veterinary Medicine*. 94,1-2.

- Plasse, D., Fossi, H., Hoogensteijn, R., Verde, O., Rodriguez, R., Rodriguez, M.C. & Bastidas, P., 1995. Growth of F1 *Bos taurus* x *Bos indicus* vs *Bos indicus* beef cattle in Venezuela. I. Weights at birth, weaning and 18 months. *J. Anim. Breed. Genet.* 112, 117-132.
- Raphaka, K., 2008. Estimation of genetic and non-genetic parameters for growth traits in two beef cattle breeds in Botswana. MSc. thesis, University of Stellenbosch, Matieland, South Africa.
- Raphaka, K., & Dzama, K. (2009). Sex of calf and age of dam adjustment factors for birth and weaning weight in tswana and composite beef cattle breeds in Botswana. *South African Journal of Animal Science*, 39(4), 296-300.
- Renquist, B.J., Oltjen, J.W., Sainz, R.D., Calvert, C.C. Effects of age on body condition and production parameters of multiparous beef cows. *J Anim Sci.* 84(7):1890-5.
- Rumph, J.M. & Van Vleck, L.D., 2004. Age-of-dam adjustment factors for birth and weaning weight records: A review. *Genet. Molec. Res.* 3 (1), 1-17. SAS, 2004. Statistical Analysis System user's guide (Version 9). SAS Institute Inc., Cary, North Carolina, USA.
- Scholtz, M.M. (2005). The *potential* of the Nguni as a dam line in terminal crossbreeding. *J. Ani. Sci.* 47, 37-41.
- Sharma, A.K., Willms, L., Hardin, R.T. & Berg, R.T., 1982. Sex of calf and age of dam adjustments for some performance traits in two populations of beef cattle. *Can. J. Anim. Sci.* 62, 699-708.
- Spitzer, J. C., Morrison, D. G., Wettemann, R. P., & Faulkner, L. C. (1995). Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. *J. Anim. Sci.* 73(5), 1251-1257.
- Swiger, L.A., Koch, R.M., Gregory, K.E., Arthaud, V.H., Rowden, W.W. & Ingalls, J.E., 1962. Evaluating pre-weaning growth of beef calves. *J. Anim. Sci.* 21, 781-786.
- Tawonezvi, H.P.R., 1989. Growth of Mashona cattle on range in Zimbabwe. I. Environmental influences on liveweight and weaning gain. *Trop. Anim. Hlth. Prod.* 21, 37-42.
- Taylor, G.I., Swanepoel, F.J.C., Webb, E.C., Stoebel, A., 2008. Effect of heifer frame size on their subsequent reproductive performance and preweaning performance on their calves. *Australian Journal of Experimental Agriculture.* 48, 945-949.
- Tiki, B., Addis, M., 2011. Distribution of ixodid ticks on cattle in and around Holeta Town, Ethiopia. *Global Veterinaria*, 7(6): 527-531
- Turkson, T.K., 2009. Client's satisfaction with delivery of animal health-care services in peri-urban Ghana. *Preventive Veterinary Medicine.* 90, 153-159.

Turton, J.,1999. Tick-borne diseases in ruminants. Directorate Communication, National Department of Agriculture in cooperation with ARC-Onderstepoort Veterinary Institute [web]<http://www.nda.agric.za/docs/Infopaks/ticks.htm/> [Accessed: 6 October 2014].

Vizcarra ,J.A., Wettemann, R.P., Spitzer, J.C., Morrison, D.G. Body condition at parturition and postpartum weight gain influence luteal activity and concentrations of glucose, insulin, and nonesterified fatty acids in plasma of primiparous beef cows. *J Anim Sci.*76(4), 927-36.

Webb, E.C. (2016). Growth, size and efficiency of Nguni cattle for the optimum adaptation and reproduction efficiency. *Nguni journal* , pp. 43-46.

Webb, E.C., Casey, N.H.,2010. Physiological limits to growth and the related effects on meat quality. *J.Livestock Sci* 130: 33–40.

Webb, E.C., Mamabolo, M. J., 2004. Production and reproduction characteristics of South African indigenous goats in communal farming systems. *South African J. Anim. Sci.* 34, Supplement 1.

Weddle-Schott, L. (2012). Reproduction and breedin: Reproduction Success in the Cow Herd. University of Minnesota Beef team.

Willadsen, P., 2006. Tick control: Thoughts on a research agenda. *Veterinary Parasitology* 138: 161–168.

Wymanna, M. N., Bonfoha, B., Schellinga, E., Bengalyb, S., Tembelyb, S.,Tannera, M., Zinsstaga, J. (2006). Calf mortality rate and causes of death under different herd management systems in peri-urban Bamako, Mali. *Livestock Science.* 100(2–3), 169-178.

Rajput, Z.I., Hu, S., Chen, W., Arijo, A.G., 2006. Importance of ticks and their chemical and immunological control on livestock. *Journal of Zhejiang University Science.* Doi: 10.1631/jzus.2006.B0912.

Renquist, B.J., Oltjen, J.W., Sainz, R.D., Calvert, C.C., 2006. Effects of age on body condition and production parameters of multiparous beef cows. *J Anim Sci.* 84(7), 1890-5.

Van Rooyen, J., Introduction to the Mnisi Community Programme and the latest findings regarding baseline research on ecosystem health, cattle production- and health management at the wildlife/livestock interface within the GLTFCA, RSA

Vizcarra, J.A., Wettemann, R.P., Spitzer, J.C., Morrison, D.G., 1998. Body condition at parturition and postpartum weight gain influence luteal activity and concentrations of glucose, insulin, and nonesterified fatty acids in plasma of primiparous beef cows. *J Anim Sci.* 76(4), 927-36.