FACTORS AFFECTING PRODUCTIVE LIFE AND FERTILITY IN NGUNI COWS

By

MAWANDE NGAYO

Dissertation submitted to the Faculty of Natural and Agricultural Sciences,

Department of Animal, Wildlife and Grassland Sciences,

University of the Free State,

In partial fulfillment of the requirements for the degree

MAGISTER SCIENTIAE AGRICULTURE

Supervisor: Dr. M.D. Fair

Co-supervisor: Prof. F.W.C. Neser

: Prof. M.M. Scholtz

Bloemfontein, July 2017

Declaration

I, Mawande Ngayo declare that this thesis / dissertation, which I hereby submit for the degree in MSc. Animal Science at the University of Free State, is my work and has not been submitted by me or anyone else for a degree at any other tertiary institution .

Signature………………..

Date……………………..

Table of Contents

List of Tables

List of Figures

ACKNOWLEDGEMENTS

This research study was made possible by the following people and institutions, to whom the author wishes to, express his sincere gratitude and appreciation:

Agricultural Research Council (ARC) for financial support since beginning of the study to completion and also for exposure to advanced knowledge in the field of Animal Breeding through a number of workshops.

Dr. M.D. Fair, who acted as direct supervisor, for his valuable guidance, support, advice and assistance, constant encouragement, constructive criticism and understanding throughout the study.

Prof. F.W.C. Neser and Prof. M.M. Scholtz, who acted as co-supervisors, for their valuable guidance, advice, assistance and hospitality towards me.

Mr. Michiel Van Niekerk and Mr. Pat Hobbs for making data from their herds available for use in the study

Northern Cape department of Agriculture, for allowing use of data from their herd in the study.

SA Stud Book for assistance in acquiring and withdrawing data from their LOGIX system.

Prof. V. Ducrocq for statistical assistance in use of Survival kit and Survival analysis.

My family, for their encouragement which enabled me to carry out this study.

My mother, sisters, and friends for their continuous support, especially to my late older brother, Sicelo Ngayo, who believed in me.

And above all, I wish to thank God Almighty, who gave me life and strength to complete this study.

CHAPTER 1

GENERAL INTRODUCTION

1.1 BACKGROUND

Several factors have an effect on beef cattle financial gains; however, to keep heifers in the productive herd is difficult for beef cattle enterprises (Schwab & Hoyer, 2013). Szabo & Dakay (2009) defined cow longevity as a length of productive life which is defined as the number of years from the first date at calving to culling or death date. According to Parish (2010) a cow is culled or removed from the productive herd because of her incapability to remain productive as a breeding cow and dam in the herd. Not similar to cows that are involuntarily removed due to death, cows that are culled stand a chance of being restored into the breeding herd by improving their health and body condition (Parish, 2010). Rogers *et al*. (2004) postulated that the longevity of breeding cows has a major impact on economic efficiency in beef production systems. Cow longevity is directly related to farm profit (Forabosco, 2005). However, for sound revenue returns, cows that remain in production further than their breakeven age must redress for cows that are culled earlier (Snelling *et al*., 1995). Sanders (2012) stated that longevity is correlated to other prominent traits, and it is difficult to isolate the importance of longevity itself, from the weight of traits that are related to it.

It is quite simple to measure longevity as a trait and one common way to record it is through measuring the cow's productive life length, being recorded as the time interval between first calving date to culling date (Forabosco *et al*., 2004). A beef cow's length of productive life is a convoluted trait that demonstrates the performance of a cow throughout her total herd life, which is verified largely by her fertility, maternal potential, health, and survival of herself and her calves (Martinez *et al*., 2004). A challenge when it comes to measuring longevity is the time it takes for the information to become available, which is relatively long and that in turn decreases the reliability of information for young animals (Forabosco *et al*., 2004). According to Du Toit *et al*. (2012) selection for length of productive life is hindered by the long period of time required for cow's complete records to be available.

Burnside & Wilton (1970) postulated that selection for longevity is only possible through indicators of length of productive life which can be obtained early in life and demonstrate a genetic difference. The reliability of proofs (Estimated Breeding Values) for young bulls increases when indirect measures for longevity are used and therefore stimulates the use of younger bulls, which in turn decreases generation intervals (Forabosco *et al*., 2004). A cow's prolonged productive life in a herd is due to the good health and state of fertility, which results in less veterinary care and insemination expenses (Essl, 1998). Durr e*t al*. (1999); Vukasinovic *et al*. (2001); Pachova *et al*. (2005); Sewalem *et al*. (2005) and Bielfeldt *et al*. (2006) postulated that the age at first calving does not have much effect on the length of a cow's productive life, even though a particular trend of culling risk increases with later age at first calving is observed. However, Patterson *et al*. (1992) reported that heifers that calve before the age of 24 months have an increased productive life in a herd in relation to heifers that calve later than 24 months of age. Several studies have indicated a favourable correlation between calving early in the calving season and increased cow's productive life in the herd (Deutscher *et al*., 1991; Patterson *et al*., 1992 and Arthur *et al*., 1993).

Prolonged intervals after calving and improved rebreeding rates of females calving early are common signs of increased longevity and result in the tendency of cow-calf operators to select for the older and bigger heifers to increase their chances of reaching early puberty, early breeding and calving early in the season (Mousel *et al*., 2012). Longevity is largely affected by environmental conditions, nutrition, management, and breeding conditions and it is a lowly heritable trait (Szabo *et al*., 2006). However, there might also be certain differences between the different breed types. Sanders (2012) reiterated that it is a simple task to consider why cows leave the breeding herd compared to considering why other cows remain in the productive herd longer. The current study focuses on factors affecting beef cow productive herd life and reproductive performance on three herds reared under different environmental conditions in South Africa.

1.2 THE PROBLEM STATEMENT

One of the main challenges of cow productive herd life is its diverse approaches to define and measure it across different countries. Szabbo & Dakay (2009) reiterated that, in beef cattle operations there is less information with regards to associated traits that have an effect on length of a cow's herd life. In the South African beef industry and beef cattle farming across the globe there is not enough information about factors affecting beef cow's length of productive life. In dairy cattle clear definitions exist for productive herd life in different countries which can lead to a variety of models being used for the genetic evaluation of productive herd life (Solkner & Ducrocq, 1999; Veerkamp *et al*., 2001; Caraviello *et al*., 2004). However, very little has been done in beef cattle. Unfortunately, the time required for cows to have complete records hinders selection for cow productive herd life (Du Toit *et al.*, 2012). The main problem that appears with direct measures of the length of productive life, is censoring. This problem arises from the fact that the measure of true length of productive herd life can only be measured after the animal has been culled. This means data for productive herd life of daughters of a particular sire will normally only become available after the death of that sire, mainly because of the long productive life of cows (Forabosco, 2005).

Rogers *et al*. (2004) stated that the genetic improvement of productive life may remain a challenge because of longer inter-calving periods and relatively slow response per unit of selection applied; this is imposed by the comparatively low heritability and lack of early indicators of productive life expressed in primitive life stages. A challenge linked with productive life is that, all measures are mostly influenced by herd management and other non-genetic factors. Generally, productive herd life of the Nguni beef cows is longer than that of dairy cows (Sanarana, 2015), which means that it will take more time to get a precise or reliable productive herd life estimate.

1.3 OBJECTIVES OF THE STUDY

In the past decade there have been indications of growing interest in research on the South African indigenous cattle breeds, such as the Nguni, from a number of researchers, animal breeders and government. Although the main classification to a large extent is based on phenotypic data and type description (Nguni Breeders Society, 2008), there is still not enough information available on factors affecting Nguni cow productive herd life and fertility. To date, no studies have been carried out on Nguni beef cow productive herd life. The Nguni cattle breed is one of the oldest indigenous beef breeds in South Africa. Population differentiation among Nguni cattle performance is expected due to geographical isolation (Sanarana, 2015).

The specific objective of the study is as follows:

- The main objective of the current study was to investigate traits that could possibly affect Nguni cow productive herd life and fertility using data recorded from the South African Nguni Breeders Society from three herds reared under different environmental conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The length of productive herd life measures the complex ability of a cow to stay in the cowherd and demonstrates the potential of a cow to reproduce, wean calves, remain sound and disease tolerant. Szabo & Dakay (2009) reported that breed type, calving season and calving difficulty (dystocia) have significant effects on beef cow longevity. According to Dalstead & Gutierrez (1989) the period of time a cow must stay in the herd to return a financial gain to the enterprise is dependent on the heifer price of purchase or opportunity costs if breeders raise their own replacement heifers, sale of calves, feed costs, cull cow value and interest rate.

Sanders (2012) stated that besides death and culling, beef cows can be removed from a herd for many other reasons, such as cow sales because of drought, lessening of herd size due to selling land or termination of contract of lease on pasture land, young productive cows sale as breeding cows, or switching to a different breeding program. Saxton *et al*. (2014) reported that increased costs linked with early culling of a cow from the breeding herd, which include development costs of young females as replacements, increased depreciation costs and inferior productivity of young females in comparison with mature cows.

Discovering an early predictor of a cow's potential revenue return is of great importance for breeders because lifetime profitability traits of a cow can only be recorded at a later stage, normally after the cow has been culled from the breeding herd (Forabosco *et al*., 2004).

2.2 THE NGUNI CATTLE BREED

According to the Nguni Breeders' Society (2008), the Nguni cattle breed is arguably one of South Africa's most popular indigenous cattle breeds. However, all over the developing world, various countries have put their native livestock populations at risk by introducing exotic breeds for crossbreeding programs (Scholtz *et al*., 2008). It is suggested that this practice poses a threat to the existence of the local Nguni cattle breed type (Ramsay, *et al*., 2000), if it is not handled appropriately (Scholtz *et al*., 2008).

The Nguni name has been derived from the black African people who are collectively known as the Nguni speaking people (Schoeman, 1989). Hanotte *et al*. (1998) reiterates that this breed is considered as one of the sub-types of Sanga cattle which originated from the imported Arabian Peninsula bulls. However, a recent study by Makina *et al*. (2016) indicates that there is very little evidence of *B. indicus* in the southern African Sanga and that they can be described as a taurine tropical adapted breed, which makes the breed types fairly unique. Bester *et al*. (2003) stated that this breed was brought along the eastern and the southern regions of Africa by fugitive people who migrated from the North, Central and West Africa escaping from the environmental pressures of war and trade.

Until a few decades ago the commercial beef sector of South Africa perceived Nguni cattle as inferior due to low production outputs (Bester *et al*., 2003). However, some commercial farmers valued this breed for its adaptive traits and used it in uncontrolled crossbreeding programs (Matjuda, 2012). A Nguni herd led to the establishment of the Bartlow Combine Station in 1954 (Kars *et al*., 1994). A couple of years later (in 1959), the national recording schemes of all beef cattle were established (Hofmeyr, 1994) while in 1986 the Nguni Cattle Breeders'Society was established (Scholtz & Ramsay, 2007).

Currently, a number of South African universities (University of Fort Hare, University of Pretoria, University of Kwazulu Natal and University of the Western Cape), research institutions (Mara Research Station, Vaalharts Research Station and the Animal Production Institute of the Agricultural Research Council) as well as farmers are keeping populations of stud Nguni herds for breed conservation, research and commercial purposes.

2.3 LENGTH OF PRODUCTIVE HERD LIFE

There are continuous efforts by animal breeders to increase the average length of productive life of domestic animals. Mousel *et al*. (2012) reported that heifers that have their first calves early in the calving season have an increased productive herd life and weaning weight in comparison to heifers that calve later in the calving season. Rogers *et al*. (2004) reiterated that calving difficulty (dystocia) seems to be a significant risk factor that has an impact on early culling of beef cows and breeders must look for ways to reduce its prevalence or ease its effects. Saxton *et al*. (2014) indicated that beef cow productive herd life has an important effect on the backbone of the cow-calf production system that keeps ownership of the calves by means of finishing or fattening phase of the enterprise during animal harvest. A prolonged length of the productive lifetime decreases the number of cows in the first costly period of their life, which is from birth to first calving (Meszaros *et al*., 2008).

2.4 PHENOTYPIC MEASURES OF PRODUCTIVE HERD LIFE

Productive herd life is a useful trait that varies highly and it takes small changes in productive life to greatly influence herd profitability (Cushman *et al*., 2013). Researchers postulate that the productive herd life is a fitness and survival indicator, but traits are measured, analyzed and defined in different ways in each country (Solkner *et al*., 2000). Commonly the length of productive herd life is measured as the period of time from first calving until death; this measure demonstrates the ability of a cow to avoid being culled by the farmer (Meszaros *et al*., 2008). Usually if the measure is modified for within-herd production variation, it is referred to as functional longevity and this trait expresses the cow's ability to avoid involuntary culling (Ducrocq *et al*., 1988). Productive life is regarded as the more appropriate measurement of the ability of an animal to remain in its herd to avoid involuntary culling (Vollema, 1998), while Boldman *et al*. (1992) defined true productive herd life as the ability of an animal to delay culling. According to Rogers *et al*. (2004) functional herd life has a heritability estimate of 0.14. Van der Westhuizen *et al*. (2001) reported a heritability estimate for productive herd life to be 0.08 in the South African Afrikaner beef cows. In this regard, Rogers *et al*. (2004) implicated that genetic improvement of productive herd life will be difficult due to this relative low heritability and the lack of indicators of longevity expression early in life.

Du Toit *et al*. (2009) reported that there is a genetic difference for productive herd life to allow for genetic upgrade through selection, even though the response to selection could be slow because of the low heritability estimates. Rendel & Robertson (1950) outlined an economic measure of productive herd life importance and reported that prolonged productive herd life may boost profits by reducing annual replacement cow expenses, extending herd production through an increase in number of cows in the high producing age groups, reducing the number of replacement cows to be reared, and consequently allowing an increase in productive herd size. Tanida *et al*. (1988) stated that weaning weight of calves produced by each cow acquired over her lifetime is a complete measure of fertility, maternal ability, milking capacity and cow survival. This can be taken as an essential measurement of lifetime production.

2.5 CULLING

2.5.1 Introduction

The importance of longevity is determined by the opposite value of culling and the cost of replacement (Garcia *et al*., 2015). Each year beef cow managers are faced with the question of which animals to cull and replace from their herd (Melton, 1980). Whittier (2007) stated that the first management tool that should be considered for cow-calf producer enterprise is to cull poorer performing cows and retain their value at the time when the sales for cows allow for some financial gain. Culling can be either voluntary or involuntary. For an example, when the main reason for removal is low milk production and the cow is actually healthy and fertile, the removal can be assigned to voluntary culling (De Vries *et al*., 2010). Whereas involuntary culling occurs when health related conditions such as illness, injury, death or infertility force the farmer to remove a productive, otherwise profitable cow from the herd (Weigel *et al*., 2003 and Ahlman *et al*., 2010). The opportunities for voluntarily replacement are limited by high involuntarily culling rates (Van Arendonk, 1988 and Rogers *et al*., 1989). Economic considerations form the main basis on replacement decision; i.e., the breeder expects higher revenue returns by replacing the cow than by keeping her in the breeding herd (Van Arendonk, 1986).

2.5.2 Culling criteria

Sanders (2012) postulated that longevity is a composition of a proportion of different traits at which breeders put different emphasis on each trait in the culling criteria. Consequently, the impact of various traits on longevity is likely to be different between operations, environments and management, of which all these have an effect on cow herd life. A lower occurrence of involuntary culling provides a breeder with a great opportunity to select a larger number of cows based on milk production potential (Meszaros *et al*., 2008). Extending the length of the cow's herd productive life decreases annual production expenses related to raising replacement heifers, which in turn increases the number of highly productive mature cows, and decreases the number of cows that are removed involuntarily from the breeding herd (Rogers *et al*., 2004).

2.5.3 Age in relation to calving, culling and productive herd life

In a beef breeding herd, a cow is an important asset on which the subject of age distribution, regular costs, profits and setbacks in production influence replacement decisions. In other commercial herds of a particular breed type or cross in a particular environment, it may be reasonable to cull certain remaining cows at a certain age (Sanders, 2012). For every breed a cow can be highly productive for a certain number of years in the herd until she reaches an age where she is too old to conceive. Mousel *et al*. (2012) argued that selecting the heifers that had calves early in the calving season might be the easiest approach to enhance the length of a cow's herd life and profitability. He further stated that cows of the same age may be given a chance to produce additional calves to verify which cows can remain productive to advanced ages if a breeder wishes to improve genetic standard for longevity. Morris (1980) reported lifetime production to be neither greater nor significantly different when heifers first calved at 2 years compared to the age of 3 years, overall heifers calving at the age of 2 produced 0.7 more calves in their lifetime than the ones calving first at 3 years of age.

Withycombe *et al*. (1930) demonstrated an advantage of calving at 24 months compared to 36 months of age in relation to lifetime productivity. Heifers that calved at 24 months of age had a decreased calving rate of approximately 14% at 36 and 48 months of age compared with heifers that first calved at 36 months of age. However, they would eventually perform similarly (Withycombe *et al*., 1930). However, McCampbell (1921) postulated that a cow never fully recovers from calving at 24 months of age and added that neither she nor her calves will be as large as they should have been had she calved at 36 months instead, especially if the feeding status is not properly adressed. Grobler (2016) also indicated that it might be more viable to breed Bonsmara heifers in an extensive production system in the Sourish Mixed Bushveld region of South Africa at 26 months age to calve at 35 months of age for the first time.

Calving date for first calf females can affect cow longevity and productivity (Endicott *et al*., 2013). Calving late in the current season may increase the number of cows that either calve later or not conceive at all in the following calving season (Burris & Priode, 1958). Rogers *et al*. (2004) and Cushman *et al*. (2013) observed that heifers calving earlier in the calving season stayed in the breeding herd longer compared with heifers that had their calves later in the calving season.

2.5.4 Risk factors for culling

Culling reasons in dairy cattle are the consequences of inherent cow components particularly reproductive status, milk production, health and environmental factors such as the availability of land and replacement heifers or parlor and prices (Ahlman *et al*., 2010 and De Vries *et al.*, 2010). Beaudeau *et al*. (2000) experienced that calving difficulty and udder related disorders such as mastitis and teat injury have more distinct direct effects on culling risk. Rogers *et al*. (2004) reported that cows that experienced calving difficulty (dystocia) to be at a higher risk of being culled compared to the ones that calved with no need of assistance. Beaudeau *et al*. (2000) reported an effect of diseases which is modified for milk production on longevity to be less significant, compared to the greater effect of low milk yield and poor reproductive performance. Pinedo & De Vries (2010) speculated that prolonged post-partum intervals were also linked with high risk of culling throughout successive calvings. De Vries *et al*. (2010) reported that there is a 3 to 7 times lower risk of culling cows gestating compared to non-pregnant cows.

Fetrow *et al*. (2006) stated that culling reasons are often more than one, including lower milk production or other issues and he also mentioned that culling is an economic decision. De Vries *et al*. (2010) postulated that in recent years there has been presumably less cullings based entirely on a cow's physical aspects, such as udder and legs, compared to 30 years ago. This is due to an appreciably genetic progress in physical traits of cows over the years (Dechow *et al*., 2003). Integrating genetic improvement enhances the likelihood of an older cow being culled, in turn reduces the expectation of an older, genetically poor cow staying in the herd from one period to the next (Mathews & Short, 2001). Other possible reasons why cows could be culled or removed from a breeding herd that may be more applicable to beef cows: are sales of cows due to drought, cutback in herd size due to selling land or loss of lease on pasture land, the sale of young productive females as breeding cows, or shifting to a different breeding program or production enterprise.

2.6 BODY CONFORMATION TRAITS AND THE LENGTH OF PRODUCTIVE LIFE

Physical appearance traits that classify the udder, legs and feet, and mostly type have moderate to high heritability making selection appreciably effective (Zavadilova & Stipkova, 2012). As a result, several studies strived to evaluate conformation characteristics that can be used as key indicators of productive life. A number of studies (Rogers *et al*., 1989; Burke & Funk, 1993; Vollema & Groen, 1997; Cruickshank *et al*., 2002 and Vacek *et al*., 2006) have investigated the correlation between productive life and physical traits. In most cases conformation traits demonstrate a substantial correlation to productive life that portrays the potential of a cow to delay involuntary culling. Larroque & Ducrocq (1999) reiterated that between the physical traits, the udder, leg and foot traits appear to be the most significant ones, but the proclaimed genetic correlations are determined by the analyzed herds and differed when the herds changed with time (Vollema & Groen, 1997).

Dekkers *et al*. (1994) postulated that for financial gain or production efficiency, the main goal for genetic selection for conformation must be to increase productive life. Miglior *et al*. (2001) reported that animals with lower somatic cell counts, fine legs and udder, high milking ability, calving ease and correct rump angle tend to survive longer than the average of the herd. Strapak *et al*. (2005) and Vacek *et al*. (2006) argued that a good fore udder attachment, high attachment of the rear udder, firm central ligament, closer front teat placement and fairly long teats as significant traits for a long productive life in dairy cattle. Strapak *et al*. (2010) reported that cows with firm conformation of the rear legs, the fetlock and the feet are likely to have a longer productive life regardless of breed type which is similar to the findings by Solkner & Petschina (1999), Hamann & Distl (2002) and Strapak *et al*. (2005). Bouska *et al*. (2007) discovered that heifers with the low growth rate have a relatively longer productive life than those with average to high growth rate. Hansen *et al*. (1999) reported that Holstein dairy cows with smaller body size obtained a longer productive life of up to 6 to 7 years of age compared to dairy cows with a bigger body size.

2.7 SELECTION CRITERIA

2.7.1 Introduction

The selection criteria is the characteristics or traits used in the genetic predictions of the breeding values for animals. The main goal of all selection programs must be to improve traits of economic importance. In- order to increase profitability of the beef cow-calf production system, one of the main the selection criteria should be extended productive herd life. When traits are easy to measure, success is highly dependent on the efficient use of the additive genetic variance (Kluyts *et al*., 2003). In relation to this, Rogers *et al*. (2004) stated that the comparably low heritability and the absence of indicators of productive herd life conveyed early in life indicate that the genetic improvement of productive life will probably remain low, because of prolonged generation intervals and relatively lower response per unit of selection applied. Hence, new methods of predicting productive herd life in cattle are needed. Therefore, collective consideration of correlated traits measured early in life and productive herd life may enhance early prediction (Szabo & Dakay, 2009).

2.7.2 Early indicators (Type traits)

Type traits, such as those that can be measured early in life may be useful as productive herd life predictors (Vollema, 1998). Type traits are commonly obtained early during the productive life and are simple to measure. They also have a higher heritability than productive herd life that normally ranges from 0.08 to 0.49 (Daliri *et al*., 2008; Campos *et al*., 2012). Therefore, genetic measures for direct productive herd life based on the number of culled cows must be combined with indirect knowledge based on early indicators, such as type traits (Campos *et al*., 2012). However, information of genetic correlations between type traits and productive herd life are required and therefore, a proper identification of type traits to be used as early predictors are necessary (Sewalem *et al*., 2005). In dairy cattle breeding certain type traits correlate with productive herd life and it is those traits that are included in the selection indices which facilitate greater response in productive herd life (Larroque & Ducrocq, 1999; Baumung *et al*. 2001 and Vukasinovic *et al*., 2002). Martinez *et al*. (2004) reported that selection for length of productive herd life, given different opportunities to be alive (more years after first calving) and lifetime production defined as the number of calves born, number of calves weaned and cumulative weaning weight by six years after first calving would be feasible. However, it will probably be slow because of low estimates of heritability and possible prolonged generation intervals. This is supported by Jairath *et al*. (1994) who suggested that, because of the low heritability of total lifetime performance traits, direct selection progress will be slow.

2.7.3 Incorporating productive herd life into the selection criteria

Du Toit *et al*. (2009) states that if genetic parameters for productive herd life traits are known; it can be used in breeding programs. Breeding organizations need to evaluate the associated importance of productive herd life in comparison to other traits in taking steps to include it into the breeding programs (Forabosco, 2005). The common breeding goal in beef cattle is to attain a modern generation of animals that are more fitting to the forthcoming future production conditions than their parents (Forabosco *et al*., 2004). Well designed and implemented breeding programs form the backbone of high estimate of cost-effective genetic improvement in commercial beef production systems (Banga *et al*., 2014) and thorough breeding objectives form an essential component of such programs (Lopez-Villalobos & Garrick, 2005).

Productive herd life is inter-linked to other valuable traits frequently included in breeding programs and therefore, it is not easy to isolate its value from the value of traits that are related to it (Sanders, 2012). The main challenge for productive herd life inclusion in selection programs is the slow recording of performance data and the highly computational requirements to include survival in proportional hazard models (Van Melis *et al*., 2010). Therefore, as stated previously, identifying a longevity-linked trait that can be measured early in life could be very important to enhance selection progress. Reproductive performance as one of the traits related to cow productive herd life is one of the most economically significant traits in beef cattle (Rogers *et al*., 2004). It can be argued that, if reproductive performance is included as a criterion for culling, productive herd life can be the most economically important trait to the cow-calf producer (Du Toit *et al*., 2009). Different breeders place different emphasis on different traits in their breeding programs. Sanders (2012) argued that the effects of the relationship of the different traits with productive herd life can differ between operations and that the differences in the environmental and management can affect the cow's length of productive life.

2.8 FACTORS AFFECTING COW FERTILITY

2.8.1 Introduction

The important goal in maintaining beef cow herds is primarily to achieve reproduction and to convert fodder into commodities useful to man (Klosterman, 1981). The main objective of the beef cow herd is calf production. It therefore follows that the reproductive rate of the cow herd plays a significant role in the total productivity of the beef production system. The rate of pregnancy of cows and the survival rate of the calves are of critical importance in determining production efficiency of the cow herd. The calf growth rate also plays an important role in cow production efficiency; however, its effect is only significant when reproductive performance is at a high level.

2.8.2 Cow fertility

In the South African commercial beef sector, calving percentage is estimated at 62 % and fertility is considered as the major component that influences the overall herd production in beef cattle (Grobler *et al*., 2013). Fertility is an important aspect of production efficiency in beef production; and the aims of cattle producers are for each female to produce a healthy calf every year (Lopes *et al*., 2013). Cow fertility is a complex trait that is affected by a number of genetic and environmental factors from the time a cow is introduced to a bull until the time her calf is weaned. Since reproduction is a major role player in the whole economy of a cattle farm (Louca & Legates, 1968 with Esslemont, 1974), it is important that any failure in reproduction should be traced to its main source with immediate effect (De Kruif, 1978). Good characterization of cow fertility is notable by cows that return to cycle as soon as possible after calving, showing strong signs of oestrus, having a high chance to conceive when inseminated or mated at the correct time, and their ability to carry the resulting foetus (Zavadilova & Stipkova, 2012). The success of any breeding program highly depends on cow fertility. The notable cause of economic loss in the beef industry is reproductive failure and most of this loss occurs because cows do not conceive during a specific breeding season (Perry *et al*., 2011).

Most breeding programs give more weight to yield and type traits than the reproductive performance in selection indices (Baumung *et al*., 2001 and Solemani-Baghshah *et al*., 2014). According to De Kruif (1978), when there is a good understanding of the many factors which have an influence on fertility in cattle populations, a detailed analysis and clear interpretation of data on reproduction can be made. Thus, only then can a precise conclusion on fertility be made and can measures be taken that will lead to the minimisation of any chance of reproduction failure (De Kruif, 1978). Several reports indicate that poor reproductive performance, results in prolonged inter-calving periods and increases culling risk and cost of replacement (Pryce *et al*., 2000; Kadarmideen *et al*., 2003 and Sewalem *et al*., 2008). Early signs of heat and conception during the mating season and maintenance of pregnancy are basic indicators of a fertile cow (Haile-Mariam *et al*., 2003). Pryce *et al*. (2000), Weigel & Rekaya (2000) and Haile-Mariam *et al*. (2003) all stated that fertility traits that are involved in the display of oestrus signs after calving are highly heritable compared to the ones involved in conception. Philipsson (1982) and Hermas & Young (1987) concluded that additive variation is considerable, even though the heritability estimate for fertility is normally low. Ranberg *et al.* (1997) stated that the high phenotypic variation and the great impact of the environment on fertility traits are said to be the likely reasons for considerable additive variation (Ranberg *et al*., 1997).

The following are common reproductive targets for a beef cow herd:

- 365 days inter-calving period.
- <5% cows culled annually as subfertile.
- >95% of cows calving to wean a calf.

- Heifers calving at 24-26 months of age under intensive conditions and at 34-36 months of age under extensive conditions.
- Compact calving with 80% of cows calved in 42 days.
- Replacement rate 16% to 18%.
- Constant genetic improvement of the cow herd for traits of economic importance related to reproduction.
- Calving potential and calf weaning weight.
- Close adjustment of calving date with the commencement of grazing availability in the spring. (Diskin & Kenny, 2014).

2.8.3 Effects of inter-calving period on cow fertility

In most selection programs, inter-calving period is used as a fertility trait to minimize the negative effects that selection has on fertility (Mostert *et al*., 2006). Shortening of the usual long calving seasons and increase of calving rates results in more and heavier calves of the same age weaned (Grobler *et al*., 2013). Earlier calving cows in the season have an advantage of a lengthy period to recover ahead of the following mating season and have a better chance of calving in a better body condition during the next season than the ones calving late in the season (Odhiambo *et al*., 2009). One other advantage for calving early in the season is the better opportunity to conceive in the next breeding season and these are usually the more fertile cows (Holm, 2006). Panetto *et al*. (2010) reported that inter-calving period decreased with an increase in the age of cows. Nevertheless, this may be different in the Sanga breeds of southern Africa.

2.9 HERITABILITY ESTIMATES FOR HERD LIFE USING DIFFERENT MODELS

Genetic parameters for longevity traits have been estimated by quite a number of researchers in the dairy industry with heritability estimates ranging from 0.03 to 0.13. Dentine *et al.* (1987) reported an average herd life of 1 821 days in grade Holstein cows in an analysis where the highest number of parities were six. He obtained a heritability estimate of 0.03 when using Henderson's Method 3. Jairath *et al*. (1994) implied that direct selection for lifetime performance traits hold little promise of improving due to the low heritability of productive herd life. Caraviello *et al*. (2004) reported heritability estimates for herd life ranging from 0.05 in the west of the United States to 0.13 in the northern Central region. He stated that the results may relate to differences in the magnitude of genetic variation in cow's longevity between regions, although it may also be the result of differences in accuracy of sire identification or record keeping between regions.

Vukasinovic *et al*. (2002) reported a much higher heritability estimate (0.20) for functional longevity in Simmental cattle. In a study on Czeck Fleckvieh a heritability estimate was 0.05 for functional length of productive life (Zavadilova *et al*., 2009). Using a sire model, estimates of heritability for herd life for different data sets on cows born in 1978, 1982 and 1985 were reported by Vollema & Groen (1996), decreasing from 0.14 to 0.04 with an increase in birth year. Although the heritability estimates were comparable with literature values, there were quite huge differences between years of birth. The authors implied that the population has gone through strong selection during the period considered. The study obtained similar results when analyzing the data using both sire and animal models. They concluded that when analyzing longevity traits with low heritability estimates (such as herd life) with an animal model, most information comes from the sire component and that the difference between the two models is expected to be small.

Using survival analysis, Buenger *et al.* (2001) reported a heritability estimate on the log scale of 0.116 and 0.111 in Holstein cattle for uncorrected length of productive life and functional length of productive life, respectively. Using Henderson's Method 3, Hoque & Hodges (1980) and Durr *et al*. (1999) obtained similar results. Henderson's Method 3 is based on the method of fitting constants traditionally used in fixed effects models (Djordjevic & Lepojevic, 2003). Vollema & Groen (1996) reported estimates of heritability for length of productive life of 0.14 and 0.11 for Holstein cows born in 1978 and 1982, respectively, using REML.

Buenger *et al*. (2001) obtained higher heritability estimates for uncorrected herd life (0.17) and functional herd life (0.18) in Holstein cows when using the transformation method of Yazdi *et al*. (2002) which is independent of the value of the Weibull parameter. The Weibull parameter is one of the baseline functions which are summarized by the Weibull model (Grohn *et al.*, 1997). a baseline character Jairath *et al*. (1994) reported relatively low heritability estimates for length of productive life which range from 0.07 to 0.09 in Canadian Holsteins. These are similar to those obtained by Hoque & Hodges (1980) in Holstein cattle, Van Raden & Klaaskate (1993) also in Holstein and Brotherstone *et al*. (1997) in Holstein-Friesian cows.

2.10 SUMMARY

Female fertility is one of the most important traits in beef cattle production. In spite of its importance, fertility receives little attention in most beef genetic evaluation programs (Maiwashe *et al*., 2009). Generally, the lack of inclusion of this trait in breeding programs can be related to its difficulty to record and low heritability. Breeding organizations have realized that selecting solely for higher production in an animal leads to a deterioration of the animal's health and reproductive performance, while increasing metabolic stress and reduced longevity (Rauw *et al*., 1998).

The lifetime productivity of beef cows commence from the onset of puberty and is dictated by subsequent critical events which include age at first calving, duration of the postpartum interval for each successive calving and ultimately length of inter-calving period (Diskin & Kenny, 2014). Although an early age at first calving increases cow longevity, it also decreases replacement costs. Economic weights allocated to longevity traits by farmers also have an effect on the length of productive herd life of a cow (Do *et al*., 2013).

CHAPTER 3

FACTORS AFFECTING PRODUCTIVE LIFE AND FERTILITY IN NGUNI COWS

3.1 INTRODUCTION

In the commercial beef cattle farming enterprise, cow productive life and fertility are traits of economic importance (Saxton *et al*., 2014). These traits are improved by voluntary culling and replacement of poor performing cows from the breeding herd. Improvement of these two traits allows a greater response to selection because a less number of cows have to be replaced and that increases selection intensity (Vukasinovic *et al*., 2001). However, to achieve maximum genetic improvement, information available early in life must be used to evaluate genetic merit of cows (Jairath *et al*., 1994). Contrary to huge developments in the dairy industry, including some in South Africa, there are currently no productive life studies in place for the Nguni cattle breed of South Africa. The South African Nguni cattle breed is one of the popular indigenous beef breeds that are distributed throughout the country.

The aim of the current chapter is to investigate factor that affect productive life in Nguni cows.

3.2 MATERIALS AND METHODS

A univariate trait analyses was done in three separate herds from three distinct regions, namely: Vaalharts in the Northern Cape, Perdeberg on the border between the Free State and the Northern Cape and Komga in the Eastern Cape. A univariate analyses was also done for the combined three herds, thus a total of 4 analyses were done in this chapter.

3.2.1 Experimental terrain

The study comprised of animals obtained from three different herds in three distinct regions of the country. These regions were Vaalharts in the Northern Cape, Perdeberg on the border between the Free State and the Northern Cape near Boshof and Komga in the Eastern Cape.

3.2.1.1 Vaalharts region

Records of 8 421 animals were obtained from the Vaalharts Research Station in the Northern Cape Province situated near Jan Kempdorp. The research station is located in the centre of South Africa at 51.27° South and 50.24° East at an altitude of 1 175 meters. It is in an area with sand and red soil with lime rock underneath (Theunissen, 2011). These soils form part of the Hutton group of soils and represents mainly the Manganese series (Lake, 2003). The grazing consists of a mixed *Tarchonanthus* veld (Veld type No 16b 4, Acocks, 1988). The research station has a recommended carrying capacity of 10 ha/LSU (Theunissen, 2011).

The prevailing climatic condition in the region where this research station is situated is classified as the semi-arid. It is characterized by hot summers and cold winters with frost which is a common occurrence. During December and January this region experiences the highest average temperature of 32°C while the lowest monthly average temperature of -0.5°C is experienced during July (Theunissen, 2011). During the summer months from mid-October to April, this area experience 88 percent of precipitation while the average is estimated at 450 millimeters per annum, of which most of it occurs in the form of thunderstorms (Els, 1988).

3.2.1.2 Perdeberg region

A data set consisting of 6 929 animals was obtained from a Nguni herd kept on two farms (Goedehoop and Koedoesrand) separated by 5 kilometers on the border between the Free State and the Northern Cape, near Boshof. The farms are located approximately 120 kilometers from

Bloemfontein and 40 kilometers from Kimberley. These farms are located in the central region of South Africa at an altitude of 1 254 meters; Goedehoop farm is located at 28.90620° South and 25.19692° East, while Koedoesrand farm is located at 28.89266° South and 25.23074° East.

The area is dominated by shallow Hutton Form soil types with overlying sediments of (sandstone, siltstone, and shales) of the Dwyka and Ecca strata and dolerites of the Karoo Supergroup (Rutherford & Westfall, 1986). The area is part of Veld Type 16, Kalahari Thornveld (Acocks, 1988) and according to Rutherford & Westfall (1986), the area falls into the Savanna Biome. The grazing is classified as sweet veld with predominantly grassland with occasional trees (mainly *Acacia spp*.). Grasses present are *Eragrostis superba, E. lehmanniana, Theme da triandra* and *Aristida congesta, A.* with carrying capacity of 13 ha/LSU.

The climate of Boshof is typically semi-arid, with very hot summers and mild to cold winters. The hottest months are December, January and February and the coldest months June and July. The highest monthly average temperature is estimated at 31° C occurring during December and January and the lowest monthly average temperature is 0° C and it occurs in July. The average annual rainfall is approximately ± 404mm, most of it occurs between September and December.

3.2.1.3 Komga region

A data set consisting of 12 788 animals was also obtained from a Nguni cow herd from a coastal stud farm in the Komga region of the Eastern Cape, mostly dominated by sourveld type of grasses mixed with patches of bushveld and thornveld. Komga is a small scenic village set among the rolling grasslands some 65 kilometers to the East of King William's Town. This small village is a cattle farming centre about 60 km north of East London. The word Komga means piece of clay, it is also attributed to the soil type which is dominated by clay in the whole

Komga region. The farm is located at 32.577° South and 27.888° east. Komga receives 593mm of rain per annum, mainly during summer. This region receives the lowest rainfall (16mm) in July and the highest (79mm) in March. The average midday temperatures for Komga range from 20°C in July to 26°C in February. The region is the coldest during July when the temperature drops to an average of 9.3°C during the night.

3.3 EXPERIMENTAL ANIMALS

African cattle originate from three different sources; namely (1) the domestication from Asia along the Nile Valley and onwards through Egypt; (2) a second domestication event emanated through the "horn" of Africa or from the East Coast towards and through Madagascar; and (3) a domestication event that took place in the African continent (Pienaar *et al*., 2015). The centre of origin of the primitive Sanga breeds is therefore most likely East Africa.

African cattle today can be classified into three groups: African *B. Taurus, B.indicus* and Sanga types (African hump-less *Bos indicus)* (Rege, 1999). The indicine types are mainly found in the eastern and dry parts of West Africa, whereas the Sanga types are mainly found in eastern and Southern Africa.

The South African Stud Book Annual Logix report (2014) released the recent statistics indicating Nguni as the second most popular breed being recorded after Bonsmara. These Nguni statistics included the number of herds (407) registered, individual females (54 748) and males (20 407). It must be noted that these statistics excluded the BreedPlan breeds.

According to Sanarana (2015) Nguni cattle have long productive lives as cows and can produce 10 or more calves during their productive life period. Nguni heifers mature early with high fertility and have low calf mortalities (Matjuda, 2012). Furthermore, they have good temperament and mothering ability and this is linked to the historical development of the breed (Nguni Cattle Breeders Society, 2008). Nguni cows show great efficiency and often wean calves that weigh 45-50% (153kg) of their body weight (Sanarana, 2015). They are less prone to dystocia which is attributed to their sloping rump, small uterus which limits the size of the foetus and keeps the birth weight low (Maciel *et al*., 2013). Initially, the Nguni breed was used for beef, dairy production and draft power; however, it is today mainly kept as a beef breed.

3.4 DATA SET

3.4.1 Data editing

Data and pedigree records of registered Nguni cows from the three mentioned regions were obtained from the SA Stud Book Logix information system. The pedigree data from all three herds included unique animal identification numbers, sire, and sire of sire, dam of sire, dams, sire of dam and dam of dam records.

Important information included in the original data set were the birth dates of each animal, culling date, date of death, inspection date, registration date, breeder number, owner number and ownership date. The data contained records of animals born between 1968 and 2015 from all three herds. The number of animals for the three herds is presented in Table 3.1.

Table 3.1 Number and breakdown of the three herds.

			n			
Herd	ID	Sires	Dam of Sire	Dams	Sire of Dam	Dam of dam
KM	12 788	1 349	389	2 006	364	961
PG	6 929	498	216	1 220	241	580
VH	8 421	1 228	387	1 341	392	747
Comb.	28 138	3 075	992	4 567	997	2 288

n = number; ID = Animal Identity records; KM = Komga; PG = Perdeberg; VH = Vaalharts Research Station; Comb. = Combined records.

Preliminary editing was done to ensure quality of the data to enable the use of different models in the analysis. Since productive herd life is considered in the current study, the editing criteria was carried out based on the Nguni breed-standards as described by several authors (Nguni Cattle Breeders Society, 2008; Madjuda, 2012 and Sanarana, 2015). The following records were removed from the original data set:

1. Age at first calving (AFC) records less than 512 days and greater than 1 100 days.
2. Inter-calving period (ICP) records less than 270 days and greater than 801 days.
3. Twin birth dates differing more than 24 hours.
4. Animals with more than one birth date or with no birth date or no registration number.
5. Aborted calves.
6. Animals with incorrect parentage.
7. Cows with a birth date later than that of their calves.
8. Dams older than 8 900 days.
9. Culling- or death date earlier than last calving date.

Data extracted dated at least 10 generations back. In the current study only progeny from first parity to the 15th parity was considered. All known pedigrees were used in the analyses.

3.4.2 Statistical analyses

The combined data for all available Nguni cows from the three regions was analyzed using ASREML software (Gilmour *at el*., 1997). An animal models was used to test the fixed effects to be included in the final model to predict the trait in question namely productive herd life (HL). The fixed effects tested for significance for inclusion in the model were number of parities (NP) from 1 to 15 and year of birth (NY) from 1968 to 2011. The co-variables of age at first calving (AFC) and average inter-calving period per cow (ICP) in days were also tested for significance for inclusion in the model. The GLM Procedure of SAS was used to test the significance of the fixed and co-variable effects mentioned. The final model tested for both the separated and combined herd analyses was:

$$y = X\beta + Za + e$$

Where:

y = a vector of phenotypic observations for the cows'productive herd life (HL).

X = an incidence matrix relating records to the fixed effects β.

β = a vector of fixed and co-variable effects which included:

- Number of parities (NP = 1 to 15) as fixed effects.
- Year of birth (YR = 47 years, 1968 to 2015) as fixed effects.
- Cow's age at first calving (AFC) as co-variables.
- average Inter-calving period per cow (ICP) in days as a co-variable.

Z = an incidence matrix relating records to the additive genetic effects.

a = a vector of the additive genetic effects.

e = a vector of residual effects.

Productive herd life was calculated as the difference between the first calving date and the last calving date. The inter-calving period (ICP) was calculated as the difference between the previous calf birth date and the subsequent calf birth date.

3.5 RESULTS AND DISCUSSION

In Table 3.2 Descriptive statistics of individual effects and productive herd life for all Nguni herds in the study are presented.

Table 3.2 Descriptive statistics for individual effects and productive herd life for the three Nguni herds.

Trait	Mean ± SD	Min	Max
	KM		
AFC (days)	848.10 ± 134.80	512	1 099
ICP (days)	404.50 ± 59.64	329	701
NP	7.10 ± 3.26	3	15
HL (days)	2 477 ± 1 241	688	6 088
	PG		
AFC (days)	893.40 ± 134.8	602	1 099
ICP (days)	403.50 ± 52.43	315	655
NP	7.20 ± 3.43	3	15
HL (days)	2 534 ± 1 271	669	5 864
	VH		
AFC (days)	893.50 ± 134.40	534	1 099
ICP (days)	404.20 ± 51.10	313	800
NP	7.20 ± 3.57	3	15
HL (days)	2 602 ± 1 297	655	5 813

KM = Komga herd; PG = Perdeberg herd; VH = Vaalharts Research Station herd; AFC = Age at first calving; ICP = Average inter-calving period per cow; NP = Number of parities; HL = Herd life.

The minimum age at first calving (AFC) in the KM, PG and VH herds were 512, 602 and 534, respectively. PG herd had the largest minimum AFC amongst the three herds, however, the maximum AFC was restricted to 1 099 days for all herds during editing. The obtained minimum AFC was less than the results obtained by Faraji-Arough *et al.* (2011). The means for AFC were 848.1, 893.4, and 893.5 days for KM, PG and VH, respectively. Maciel *et al.*

(2013) reported means that were higher for Nguni and Landim cattle in Mozambique (1 085 and 1 003 days, respectively).

Other notable differences amongst the three herds were in inter-calving periods (ICP). The minimum ICP was 329, 315 and 313 for KM, PG and VH, respectively, while the maximum ICP for each herd was 701, 655 and 800. The mean ICP for all three herds (KM, PG and VH) was 404.5, 403.5 and 404.2, respectively. For ICP, Van der Westhuizen *et al*. (2001) obtained a mean of 390.7 days for Bonsmara cattle in South Africa.

The minimum- (3) and maximum (15) number of parities (NP) were restricted in all herds. The mean NP was 7.1 for KM whereas it was 7.2 for PG and VH herd. The Vaalharts herd had the highest mean for productive herd life (2 602), followed by PG (2 534) and KM (2 477). The minimum productive herd life (HL) amongst the three herds (KM, PG and VH) was 688, 669 and 655, respectively. The maximum HL was 6 088, 5 864 and 5 813 for KM, PG and VH herds, respectively. The KM herd had the highest maximum productive herd life and the least minimum age at first calving (AFC) compared to the other two herds (PG and VH). In all three herds the minimum age at first calving were less than the results reported by Maciel *et al*. (2013) for Nguni cows in Mozambique.

All the fixed and co-variable effects namely number of parities (NP) from 1 to 15 and year of birth (NY) from 1968 to 2011 and the co-variables of age at first calving (AFC) and average inter-calving period per cow (ICP) in days were significant ($P<0.05$) and thus remained in the model used to analyse HL.

In Table 3.3 genetic parameters and standard errors obtained from the operational model are presented.

Table 3.3 Estimates of variance components, heritability (h^2) and standard error (± SE) for productive herd life of the three herds.

	KM	PG	VH
Phenotypic variance	19 801	9 2207	19 048
Additive variance	1 508.20	0.4000	582.98
Error variance	182 292.8	9 2206.6	1 220.40
Heritability estimates	**0.08**(± 0.022)	**0.00**(± 0.00)	**0.03**(± 0.01)

KM = Komga herd; PG = Perdeberg herd; VH = Vaalharts Research Station herd.

The results obtained showed differences in genetic parameters amongst the three herds KM, PG and VH. The differences were expected due to different environments, selection regimes and management practices. Although all three heritability estimates were low, the zero value in the herd from the Perdeberg (PG) region was surprising. The zero heritability value indicated that the variance measured for HL in the PG herd was due to the environmental effects. This observation could be due to constraints in the original data set for the PG herd. However, the results obtained in the Komga (KM) herd were in agreement with findings by Hoque & Hodges (1980); Van Raden & Klaaskate (1993); Jairath *et al*. (1994); Brotherstone *et al*. (1997). Dentine *et al*. (1987); Rogers *et al*. (1991); Boldman *et al*. (1992) reported similar results to the VH herd. This is in contrast to heritability estimates for HL obtained by Basu *et al*. (1983) in Tharparkar cows (0.69).

For example, 0.075 for Boran cattle (Haile-Mariam & Kassa-Mersha, 1994), 0.04 for Japanese Black in Hiroshima (Oyama *et al*., 1996), 0.24 for Angus (Frazier *et al*., 1999) 0.38 for

Holstein-Friesian (Ojango & Pollott, 2001) and 0.109 for Japanese Black (Uchida, 2001) were reported.

The descriptive statistics for effects and productive herd life in the combined data from all three Nguni herds used in the analysis are presented in Table 3.4.

Table 3.4 Descriptive statistics for effects and productive herd life for the combined data set.

Trait	Mean ± SD	Min	Max
AFC (days)	893.50 ± 136.40	512	1 099
ICP (days)	408.40 ± 59.54	313	800
NP	7.20 ± 3.59	3	15
HL (days)	2 542 ± 1 272	655	6 088

AFC = Age at first calving; ICP = Average inter-calving period;
NP = Number of parities; HL = Herd life; Min = Minimum;
Max = Maximum; SD = Standard Deviation.

The mean and standard deviation (± SD) for age at first calving (AFC) was 893.5 and 136.4 days, respectively. Maciel *et al*. (2013) reported 1 085 and 1 003 days for AFC in the Nguni and Landim cows in Mozambique, respectively. This is higher than the values reported by Makgahlela *et al*. (2008) (840 days) and Faraji-Arough *et al*. (2011) (811 days). The minimum age at first calving in the combined data of all three herds was 512 days while the maximum age was restricted to 1 099 days. This is less than the values reported by Faraji-Arough *et al*. (2011) where the minimum and maximum AFC were 608 and 1 277 days, respectively. The minimum inter-calving period (ICP) was 313 while the maximum was restricted to 800 days, with a mean and standard deviation of 408.4 and 59.54, respectively. The observed inter-calving period minimum and maximum in Table 3.4 is more than the one reported by Mostert *et al*. (2006) for South African cattle which were of 260 and 750 days. The results of Mostert *et al*. (2006) concurred with a report by Ansari-Lari *et al*. (2009). Maciel *et al*. (2013) reported a mean for ICP similar to the observations in Table 3.4 for Nguni cows in South Africa. The mean and standard deviation for number of parities was 7.2 and 3.59, respectively, while the minimum number of parities was 3 and the maximum 15. The mean number of parities illustrated in Table 3.4 is higher than 4.02 reported by Saeed *et al.* (1987) for Kenana cattle during their productive life. The minimum length of productive herd life (HL) was 655 days and the longest 6 088 days. The mean and standard deviation for productive herd life was 2 542 and 1 272 days, respectively. The mean estimate for HL was in agreement with findings by Goshu (2005) in Friesian-Boran crossbred cows but greater that findings by Trail *et al*. (1985) in Boran, Enyew *et al*. (2000) in Holstein and Nilforooshan & Edriss (2004) in Holstein cows who obtained values of 1 935.5, 2 197.3 and 1 716 days, respectively.

In Table 3.5 genetic parameters and standard errors obtained from the operational model for three herds combined are presented.

Table 3.5 Estimates of the variance components, heritability (h^2) in bold and standard error (± SE) in brackets for productive herd life traits from the combined Nguni dataset.

	HL
Additive variance	770.76
Phenotypic variance	2 7196
Residual variance	26 425
Heritability estimate	**0.02**(± 0.004)

HL = Herd life.

All the fixed effects that were fitted in the model were significant (P<0.05) for herd-life. The observed heritability estimate was in agreement with findings by Jairath *et al*. (1994). The estimate is the same as that reported by Vollema & Groen (1998). However, this estimate is much lower than findings by Buenger *et al*. (2001), Vukasinovic *et al*. (2002) and Sewalem *et al*. (2005) who obtained an estimate of 0.20 for this trait.

3.6 CONCLUSION

The heritability values obtained for productive herd life (HL) were low in both the combined and individual herds analysed. The heritability estimates obtained correspond to those found in the literature indicating that selection progress for productive herd life and related fertility traits is possible, but will be slow.

CHAPTER 4

AGE AT FIRST CALVING AND INTER-CALVING PERIOD USED AS TRAITS TO ASSESS COW FERTILITY

4.1 INTRODUCTION

Age at first calving and inter-calving period are two important reproductive efficiency measurements that are frequently recorded in most beef breeding enterprises. These are two of the main traits that could have a major impact on decreasing beef production costs through genetic improvement of cow fertility. For example, shortening age at first calving and inter-calving period would decrease the cost of raising replacement heifers and production costs per calf produced per year, respectively.

Fertility in cattle is highly affected by environmental, genetic, disease and management factors. Rennie *et al*. (1976) estimated the calving rate of traditionally raised Tswana cattle in Botswana as 46.4%, in comparison with 74.0% for the same breed of animals on the commercial farms. Grobler *et al*. (2013) reported a calving percentage of 62 % for the South African commercial beef sector, while Scholtz & Bester (2010) reported values of 60.8%, 47.9% and 26.9% for the commercial, emerging and communal sector, respectively.

Age at first calving (AFC) is of economic importance because it marks the beginning of an animal's productive life and therefore also affects the lifetime productivity of the animal (Ojango & Pollott, 2001). However, like many other reproduction traits, age at first calving is a lowly heritable trait and might have an optimum. Various literature reports on estimates of AFC indicate that a huge difference exists in genetic variation between breeds and also between lines within a breed. Oyama *et al*. (1996) reported a heritability estimate of 0.04 for Japanese Black in Hiroshima, while Haile-Mariam & Kassa-Mersha (1994) found a value of 0.062 for

Boran cattle. Uchida (2001) reported an estimate of 0.109 for Japanese Black while Frazier *et al*. (1999) obtained a value of 0.24 for Angus. A value of 0.38 was reported for Holstein-Friesian cattle by Ojango & Pollott (2001). However, Neser *et al*. (2014) reported a lower heritability estimate (0.12) for AFC in the Afrikaner cattle, whereas Van der Westhuizen *et al*. (2001) obtained a much higher estimate of 0.40 in South African Bonsmara cows. All these estimates are, however, higher than the 0.06 obtained by Koots *et al*. (1994).

Inter-calving period (ICP) can only be measured in cows that have two or more parities. According to Oyama *et al*. (2002) inter-calving period (ICP) seems to be an appropriate measure of fertility. However, MacGregor & Casey (1999) argued that calving date or days to calving is often used as a measure of fertility since it is considered to be less biased in seasonal mating systems. According to Nodot *et al.* (1981) inter-calving period is affected by maternal grand sire. However, Duarte *et al.* (1983) could find no significant maternal grand sire effect among cows in Brazil. Johnston & Bunter (1996) proposed that a trait such as days to calving maybe a feasible alternative to ICP. In the Hereford and Angus in Australia, Meyer *et al*. (1990) obtained value of 0.05 and 0.09, respectively.

Although Johnston & Bunter (1996) proposed the use of days to calving instead of ICP, the current Chapter focuses on both age at first calving (AFC) and inter-calving period (ICP) as traits to assess cow fertility. Days to calving was excluded from this study because no bull in bull out dates and mating lists were recorded. This information is essential for the estimation of days to calving. The aim of this chapter was to use age at first calving and inter-calving period as traits to assess cow fertility.

4.2 MATERIALS AND METHODS

Data from three registered Nguni cow herds were obtained from the locations stated in the previous Chapter and the preliminary edits were also carried out as discussed in Chapter 3.

However, additional editing and preparation of data were employed for the data to be suitable for the analysis of fertility traits using an animal model. Further editing included removal of cows that had only a single parity record. Out of the whole data set edited in Chapter 3 only age at first calving (AFC), first (ICP1) and second (ICP2) inter-calving period and average inter-calving period (AVICP) in days were retained to be analysed for this chapter. After the editing was completed the remaining data used to assess fertility traits consisted of 3 412 animal identities, 533 sires, 1 386 dams, 332 sires of dam and 666 dams of dams. Records of Nguni cows with pedigree information were analyzed using ASREML software (Gilmour *et al*., 1997) in uni- and bi-variate animal model as well as a repeatability model to obtain genetic parameters for fertility traits. Herd of origin from the three regions (Komga, Perdeberg and Vaalharts) and year of birth (from 1948-2015) were the fixed effects whereas the cow's age at first calving (AFC) was additionally included as a co-variable for the repeated model when analyzing the ICP. The uni- and bi-variate animal model that was used to obtain heritabilities, genetic and phenotypic correlations for the four fertility traits was:

$$y = X\beta + Za + e$$

Where:

y = a vector of phenotypic observations for the four fertility traits which include:

- Age at first calving (AFC) in days.
- First Inter-calving period (ICP1) in days.
- Second inter-calving period (ICP2) in days.
- Average inter-calving period (AVICP) in days.

X = an incidence matrix relating records to the fixed effects β.

β = a vector of fixed and co-variable effects which included:

- Herd of origin (Komga, Perdeberg & Vaalharts herd).

- Year of birth (YR = 47 years, 1968 to 2015).

Z = an incidence matrix relating records to the additive genetic effect.

a = a vector of the additive genetic effects.

e = a vector of residual effects.

In the repeatability model, inter-calving period (ICP) in days as a fertility trait was fitted as a repeated measures trait, age at first calving (AFC) in days was an additional co-variable with the fixed effects of herd of origin (KM, PG & VH) and year of birth (from 1968 – 2015). The repeatability model that was used to obtain genetic parameters for fertility trait ICP was:

$$y = X\beta + Za + e$$

Where:

y = a vector of phenotypic observations for fertility traits which include:

- Inter-calving period (ICP) in days fitted as a repeated trait in the model.

X = an incidence matrix relating records to the fixed effects β.

β = a vector of fixed and co-variable effects which included:

- Herd of origin (Komga KM, Perdeberg PG & Vaalharts VH herd).
- Year of birth (YR = 47 years, 1968 to 2015).
- Cow's age at first calving (AFC) in days as a co-variable.

Z = an incidence matrix relating records to the additive genetic effect.

a = a vector of the additive genetic effects.

e = a vector of residual effects.

4.3 RESULTS AND DISCUSSION

In Table 4.1 the descriptive statistics for the traits (AFC, ICP1, ICP2 and AVICP) used in the uni- and bi-variate animal model to obtain genetic parameters are presented.

Table 4.1 Descriptive statistics for age at first calving (AFC), first inter-calving period (ICP1), second inter-calving period (ICP2) and average inter-calving period (AVICP).

Trait	Mean ± SD	Min	Max	CV%
AFC	896.80 ± 142.10	512	1 099	10.90
ICP1	423 ± 105.30	270	823	15.00
ICP2	400.30 ± 91.76	275	810	11.80
AVICP	408 ± 59.58	313	844	9.50

SD = standard deviation; Min = minimum; Max = maximum; CV% = coefficient of variation; AFC = age at first calving; ICP1 = 1^{st} inter-calving period; ICP2 = 2^{nd} inter-calving period; AVICP = average inter-calving period.

The mean and standard deviation for age at first calving (AFC) was 896.8 days and 142.1 days, respectively. Wagenaar *et al.* (1986) obtained a higher mean for age at first calving (1 506 days) in Fulani-type dams in Niger compared to the one shown in Table 4.1. The minimum age at first calving was 512 days while the maximum was restricted to 1 099 days, with the coefficient of variation of 10.9 %. The first inter-calving period (ICP1) mean and standard deviation were 423 days and 105.3 days, respectively, while the minimum and maximum values were capped at 270 and 823 days, respectively. The coefficient of variation was 15.0%.

The population mean for ICP1 in Table 4.1 is less than the one reported by (Melaku, 1994), (Teferi, 1994) and (Goshu & Hegde, 2003), for F1 crosses, upgraded dairy and Friesian cows, respectively, which were 457, 456 and 450 days. The mean for the second inter-calving period (ICP2) was 400.3 days with a standard deviation of 91.76 days. The minimum and maximum were 275 and 810 days, respectively with a coefficient of variation being 11.8%. The mean obtained for ICP2 is in agreement with findings by De Vaccaro *et al.* (1977) in Brahman cattle and Faraji-Arough *et al*. (2011) in Iranian Holstein who obtained 400 days. Maciel *et al*. (2013) in Nguni cattle, Farhangfar & Naeemipour Younesi (2007) in Iranian Holstein, Chookani *et al*. (2010) in Holstein and Hultgren & Svensson (2010) in Swedish Red obtained higher values for the mean for second inter-calving period.

The observed difference between ICP1 and ICP2 means are in agreement with observations by several authors (Velarde *et al*., 1975; De Vaccaro *et al*., 1977; Dhoke & Johar, 1977; Kumar & Bhat, 1979; Ram & Balaine, 1979; Baliero *et al*., 1981; Montoni *et al*., 1981 and Oyedipe *et al*., 1982) who observed that the first inter-calving period is considerably longer than the second. The average inter-calving period (AVICP) mean and standard deviation were 408 and 59.58 days, respectively while the minimum and maximum were 313 and 844 days, respectively and the coefficient of variation was 9.5%. The AVICP mean is higher than the 382 days observed by Hinojosa *et al.* (1980) for Brahman cows in Mexico.

Estimate of variance components, genetic correlations, heritabilities (h^2), phenotypic correlations and standard errors for the fertility traits (AFC, ICP1, ICP2 and AVICP) are presented in Table 4.2.

Table 4.2 Estimate of variance components, genetic correlations (above the diagonal), heritabilities (h^2) (on the diagonal), phenotypic correlations (below the diagonal) and standard errors in brackets for fertility traits (AFC, ICP1, ICP2 and AVICP).

	AFC	ICP1	ICP2	AVICP
Additive variance	6 476.60	1 139.80	1 890.10	1 328.70
Phenotypic variance	18 238	10 691.00	8 520.00	3 337.30
Residual variance	11 762	9 551.50	6 630.10	2 008.60
Variance ratios				
AFC	**0.36**(0.06)	0.58(0.24)	0.59(0.20)	0.49(0.12)
ICP1	-0.04(0.03)	**0.11**(0.05)	0.12(0.20)	0.70(0.17)
ICP2	0.14(0.02)	0.04(0.03)	**0.22**(0.07)	0.37(0.15)
AVICP	0.10(0.03)	0.52(0.02)	0.44(0.02)	**0.40**(0.07)

AFC = age at first calving; ICP1 =1st inter-calving period; ICP2 = 2nd inter-calving period; AVICP = average inter-calving in days.

The additive, phenotypic and residual variance for age at first calving (AFC) were higher than the findings of Faraji-Arough *et al*. (2011) who obtained 1 132, 4 786 and 5 918, respectively. The heritability estimate for AFC of 0.36 was similar to the results obtained by Van der Westhuizen *et al*. (2001) in a study on a South African Bonsmara breed. A heritability estimate that was also consistent with this value was obtained by Ojango & Pollott (2001) in Holstein-Friesian cows. Makgahlela *et al*. (2008) and Goyache & Gutierrez (2001) reported heritability estimates of 0.26 and 0.27, respectively, which are considerably less than the value obtained in the current study. In addition to the above findings, reports by a number of authors indicate large differences in heritability estimates for AFC in different breeds, Haile-Mariam & Kassa-Mersha (1994) found an estimate of 0.062 in Boran cattle; Fraizer *et al*. (1999) found an estimate of 0.24 in Angus cattle; Uchida (2001) found an estimate of 0.109 in Japanese Black cattle.

The heritability (h^2) and standard error for ICP1 was 0.11 and 0.05, respectively, while for ICP2 it was 0.22 and 0.07, respectively. Brzakova *et al*. (2016) obtained similar results for ICP1 in a study carried out on beef cow fertility in Limousin cattle. Faraji-Arough *et al*. (2011)

in agreement with Makgahlela *et al*. (2008) reported low heritability estimates for ICP1 and 2 (0.03 and 0.04, respectively). Heritability estimates for these two traits are consistent with the values observed by Vergara *et al*. (2009) in Angus-Blanco cattle and Ghiasi *et al*. (2011) in Holstein cattle, who obtained 0.11 and 0.18, respectively.

The high heritability estimate of 0.40 for AVICP was surprising. However, a very high heritability value was reported by Parmar & Johar (1982) in Tharparkar cow in India (0.68) and Weitz (1984) in Nellore cows in Brazil (0.81). The genetic correlation between AFC and ICP1 was 0.58, whereas between AFC and ICP2 it was 0.59, and between AFC and AVICP it was 0.49. In the literature the genetic correlation between AFC and ICP1 was reported in the range of -0.92 to 0.53 and for AFC and ICP2 was between 0.06 and 0.4 (Frazier *et al*., 1999; Mercadante *et al*., 2000; Farhangfar & Naeemipour Younesi, 2007 and Makgahlela *et al*., 2008). Between ICP1 and ICP2 a genetic correlation value of 0.12 was observed, this was similar to results obtained by Haile-Mariam *et al*. (2003).

Olori *et al*. (2003) also reported a higher value for the correlation (0.82) between ICP1 and ICP2. Highly negative genetic correlations between AFC and ICP were reported by Fraizier *et al*. (1999) (-0.93) and Haile-Mariam & Kassa-Mersha (1994) (-0.054). Low negative phenotypic correlations were observed between AFC and ICP1 (-0.04). Positive phenotypic correlations were obtained between AVICP and both ICP1 and ICP2 (0.52 and 0.44, respectively).

Descriptive statistics for traits used in the repeatability model to assess fertility in Nguni cows are presented in Table 4.3.

Table 4.3 Descriptive statistics for ICP and AFC fitted as a co-variable in the repeatability model to assess Nguni cow fertility.

Trait	n	Mean ± SD	Min	Max
AFC	3174	894.10 ± 141.40	512	1 099
ICP	3174	401.10 ± 91.36	270	878

n = number of observations; AFC = age at first calving;
ICP = inter-calving period.

The mean for age at first calving (AFC) is less than the one reported by Neser *et al*. (2014) in a study carried out on the South African Afrikaner breed. Maciel *et al*. (2013) reported a mean for AFC that was higher than the current study (1 085 days). It is, however, in agreement with the results reported by Hare *et al*. (2006) who obtained an average value of 402.1 with a minimum and maximum value of 315 and 732 days, respectively in Jersey cows.

The estimated genetic parameters for inter-calving period (ICP) when using repeatability model to assess fertility in Nguni cows are shown in Table 4.4.

Table 4.4 Estimates of variance components and variance ratios for inter-calving period (ICP) used in the repeatability model to assess cow fertility.

	Variance	SE
Direct additive variance	381	131.74
Phenotypic variance	8 155.80	207.28
Error variance	7 774.8	75.54
Heritability estimate	0.05	0.02
Repeatability estimate	0.22	0.03

SE = Standard Error.

In a study carried out in a South African composite multi-breed beef cattle herd, Van der Westhuizen *et al*. (2001) reported a heritability and repeatability estimate that were lower than the current findings (0.01 and 0.07, respectively). Amimo *et al*. (2006) also reported low heritability and repeatability estimate for ICP in Ayrshire cattle in Kenya (0.04 and 0.09). In comparison to the heritability estimates for inter-calving period illustrated in Table 4.2 the result presented in Table 4.4 is considerably lower and within the range reported in literature.

The repeatability estimate for ICP corresponds with findings by Meyer *et al*. (1990) and Pryce *et al*. (2001). Other low repeatability estimates for ICP almost similar to findings in this study were 0.04 (Silva *et al*., 2015), 0.14 (Lopez de Torre & Brinks, 1990) and 0.085 (Yague *et al*., 2009). Likewise, in the literature a number of authors estimated repeatability for inter-calving period to be 0.071 (Haile-Mariam & Kassa-Mersha, 1994), 0.06 (Ojango & Pollott, 2001), and 0.07 (van der Westhuizen *et al*., 2001).

Bourdon & Brinks (1983) and Meacham & Notter (1987) argued that inter-calving period is not a good criterion for improving a dam's reproduction in a herd because of its low heritability and repeatability estimate.

4.4 CONCLUSION

The low heritability and repeatability estimates for inter-calving period observed in this study indicate that ICP is not the most suitable trait to use to improve a cow's reproductive performance. These results are in agreement with literature results.

CHAPTER 5

USE OF SURVIVAL KIT MODELS FOR PREDICTION OF PRODUCTIVE HERD LIFE TRAITS IN NGUNI COWS

5.1 INTRODUCTION

Productive herd life in South African beef cattle is defined as the probability that a cow remains in the herd to reach a specific age given an opportunity to reach that age (Van der Westhuizen *et al*. 2001). However, there is no study that has been carried out to predict Nguni cow productive herd life using the Survival kit models. There is no better methodology to analyze survival data other than survival analysis (Vukasinovic *et al*. 2001). The main importance in the analysis of survival data are two functions used to describe the distribution, namely; the survival and hazard function (Everitt & Hothorn, 2006). Several researchers have indicated new developments of an increasing use of survival analysis for prediction of productive herd life in animal breeding (Durr *et al*., 1999; Lubbers *et al*., 2000; Strandberg & Roxstrom, 2000 and Buenger *et al*., 2001).

The proportional hazard model is used as an alternative method for evaluation of productive herd life when using the survival analysis (Sewalem *et al*., 2004). In the survival analysis information of censored and uncensored individuals is combined. This enables proper statistical treatment of censored records and in turn accounts for the complex characteristics of longevity data (Vukasinovic *et al*., 2001). The ability of survival analysis to properly account for the complex distribution of survival data provides better fit to the data. It is possible to analyze censored data with this method, while environmental and management changes are used for a specific period of time (Allaire & Gibson, 1992).

The survival analysis is subdivided into two models which are; the Cox (semi-parametric) and the Weibull model (parametric). These models are referred to as proportional risk models. Both the Cox and Weibull models can be implemented using the Survival Kit software when analyzing continuous and discontinuous (time-dependent) variables. Najafabadi *et al.* (2016) suggested that the use of the Weibull models to estimate genetic parameters can help improve expected genetic progress if the selection to increase productive herd life is assigned in breeding objectives. The Cox model is more flexible because it contains both a nonparametric and a parametric element (Grohn *et al*., 1997). However, Grohn *et al*. (1997) after using the Cox models, reported similar results, interpretation, and conclusions as when using Weibull models. However, the Weibull models offer other advantages such as simpler computations and baseline characteristics that can be summarized with only two parameters (Grohn *et al*., 1997).

This Chapter focuses on using the Survival Kit software to analyze the productive herd life of Nguni cows.

5.2 MATERIALS AND METHODS

The data set used for analysis included combined records of 1 245 Nguni cows with pedigree information, dates of birth, calving dates, culling dates, and date of death obtained from the three regions as discussed in Chapter 3. Age at first calving was calculated as the difference between birth date and the first calving date. Productive herd life was calculated as the difference between the first calving date and the culling date (the date the cow was removed from the herd by voluntary culling). Age at first calving was restricted between 18 and 36 months. Cows with missing records of birth dates were excluded from the data set. Survival analysis focuses on expected duration of time to occurrence of an event of interest (in the case of the current study an event of interest is the occurrence of culling or death). Normally, time to an event of interest are not always observable; therefore censoring and truncation arise because of incomplete information on time (measured in days in the current study) to culling or death for some cows in the productive herd. Both censoring and truncation are used to avoid biasness in survival analysis.

All cows that had no culling or death date records were considered as censored records and were given a censoring code zero (0), other records were censored due to the termination of the study duration and were considered as right censored. The ones with culling or death date information were considered as non-censored records and given a code one (1). The data set had year records starting from 1984 to 2015. All birth date records from 01 January 1984 to 31 December 1995 were truncated because there was not enough information provided for those animal records in the data set.

A set of programs featured in the Survival Kit V3.12 (Ducrocq & Solkner, 1998) was used in the analysis of productive herd life in the Nguni herd data set. The Cox model was used to test the following:

$$h(t, z) = h(t) \times \exp[\text{year} + \text{afc} + \text{parity}]$$

Where:

h(t, z) = hazard of the cow, t days in the productive herd.

h(t) = baseline hazard function at time t.

year = fixed time-dependent effect of the year from 1996 to 2015.

afc = age at first calving as a covariate stratified into 3 classes (18, 24 and 24) in months.

parity = parity effect in categories from the 1st parity to the 9th parity.

A Likelihood Ratio Test was used to check the importance of the factors influencing the length of the functional productive life of cows. The proportion measure of variation was calculated according to the reliability (R^2) formula defined as a measure of proportion of explained variation in the model. Its formal definition is: R^2

$$= 1- (L_R / L_U)^{2/n}$$

Where:

n = total sample size.

L_R = restricted maximum likelihoods.

L_U = unrestricted maximum likelihoods.

The influence of the fixed effects was expressed as a relative culling rate, which is defined as the ratio between the estimated risk of culling and mean risk set to 1. For fixed effects that are time dependent the level with the highest uncensored records was assumed to be the average risk. This level was used for comparison with all other levels of the effect (Vukasinovic *et al*., 1997).

Effective heritability estimates were computed using the following method adapted from Jenko *et al*. (2013): h^2 =

$$(\sigma_a^2) / (\sigma_a^2 + \sigma_c^2 + 1)$$

Where:

σ_a^2 = is the additive genetic variance.

σ_c^2 = is the variance of contemporary group effects.

1 = is the standard environmental variance.

The description and characteristics of the data set are presented in Table 5.1.

Table 5.1 Length of productive herd life of Nguni data for censored and uncensored records.

Characters	Size
Total number of records	1 245
Number of censored records	665 (53.4%)
Number of uncensored records	580 (46.6%)
Min censoring time (days)	663
Max censoring time (days)	5 170
Average censoring time (days)	2 380.7
Min failure time (days)	625
Max failure time (days)	5 684
Average failure time (days)	2 354
Truncated records	188 (15 %)
Year effect	Min: 1, Max : 21
AFC effect	Min: 1, Max: 3
Parity effect	Min: 1, max: 9

Min = Minimum; Max = Maximum, AFC = Age at first calving.

5.3 RESULTS AND DISCUSSION

In Table 5.2 the results of the likelihood ratio test (-2 Δ log likelihood), DF (Degrees of freedom) and R^2 (Reliability) estimate of the full model and the model with no covariate for productive herd life for the combined Nguni data set are presented.

Table 5.2 The test statistics for likelihood ratio for year, age at first calving and parity effect for productive herd life for the combined Nguni data set.

EFFECTS	-2 Δ log-likelihood	DF	χ^2 (P=0.05)	R^2
	Including Z			
No covariate	7 008.86	0		
Year	6 643.87	19	30.14	0.25
AFC	5 969.09	2	5.99	0.56
Parity	5 792.80	8	15.50	0.62
	Excluding Z			
Year	6 230.10	19	30.14	0.47
AFC	6 450.72	2	5.99	0.36
Parity	5 969.09	8	15.50	0.57

-2 Δ log likelihood = -2 times difference in log-likelihood; DF = Degrees of freedom; χ^2 = the chi square value for P = 0.05 given the variables degrees of freedom; R^2 = the reliability square; Z = any covariate fitted in the model (Year, AFC and Parity); No covariate = the model of the likelihood ratio test without the covariates; Year = the year of the calf's birth date per parity; AFC = Age at first calving with three categories (18, 24 and 36 months); Parity = different parity categories (1 to 9).

In Table 5.2 there were noted differences observed when the model had no covariate and when each covariate was added in the model. With no covariate in the model the -2 Δ log likelihood estimate was 7 008.86 with zero DF. The sequential addition of different covariates improved the model significantly (R^2 = 0.62). No improvement was observed when excluding any of the covariates from the model as observed by the reliabilities as presented in Table 5.2. According to Grohn *et al*. (1997), the lower the value of -2 times the difference in log-likelihood, the better the model fits the data. The χ^2 values indicate that all the three factors (year, AFC and parity) fitted in the model for the likelihood ratio test were highly significant (P<0.05). A number of authors (Ducrocq *et al*., 1988 and Vukasinovic *et al*., 2001) observed that age at calving had no influence on length of productive life. However, Rogers *et al*. (1991) and Vollema & Groen (1997) reported age at first calving to be significant. The reliability estimates illustrated in Table 5.2 give an indication that the model including all Z was better than excluding any one Z from the model. Grohn *et al*. (1997) states that the more complex the model is, the more realistic it is. The model yielded a low heritability estimate of 0.02 and a standard error of 0.003. The low heritability estimate corresponds with the findings by Vollema & Groen (1997).

In Figure 5.1 Kaplan-Meier estimate of the survivor curve ± 95% CI for productive herd life and survival probability is presented.

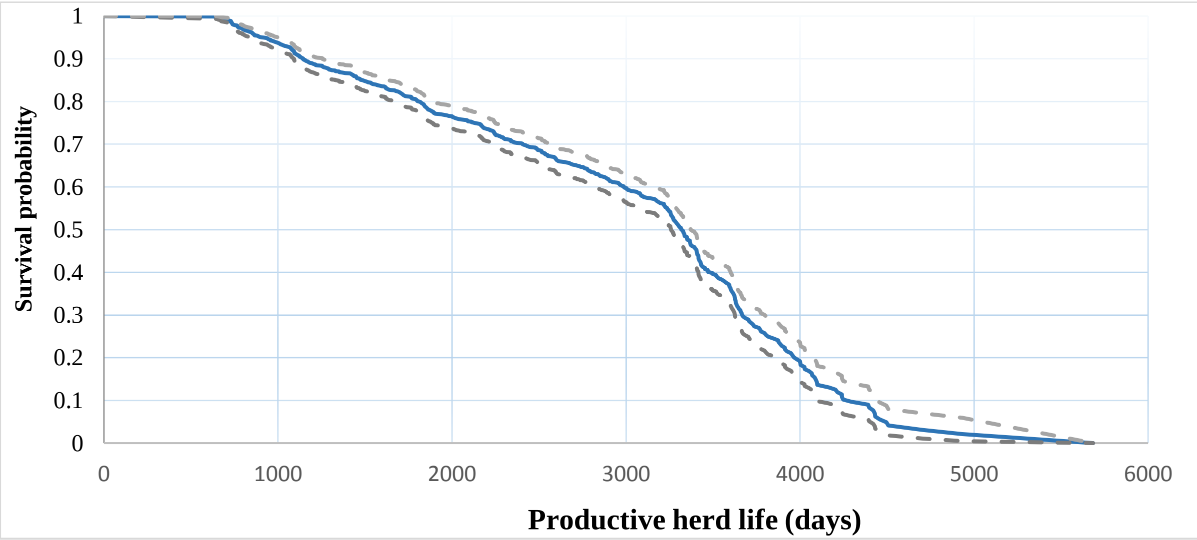

Figure 5.1 Illustrate productive herd life in days and the survival probability.

In Figure 5.1 the survival probability is constant between 0 and 900 days for herd-life for the Nguni data set. Cows that were in the productive herd during the period of 0 to 1 000 days were in their first and second parity probably between the age of 2 and 6 years. One of the culling reasons at this stage is based on age at first calving (AFC). Vukasinovic *et al*. (2001) argued that higher culling risk for older ages at first calving may be related to fertility problems.

The survivor curve shows that at this stage of productive life the culling risk was very low for more than 95% of the cows in the productive herd.

However, from 1 000 to 3 000 days the survival probability seems to be steadily decreasing. At least 50% of the cows survived up to 3 400 days in the productive herd. Survival probability progressively decreases at a high rate between 3 000 and 4 000 days about more than 60 % cows out of the productive herd were at a risk of being culled at this stage. The survival estimate dropped further down to zero at a herd-life period of 5 000 and 6 000 days and more than 95% of cows were at risk of being culled from the productive herd. Cows remaining in the herd beyond 4 000 days (around 11 years) are seasoned highly productive cows with 8 or more calves in their productive life. Skrzypek (1978) reported the age of 11 years as the cow's peak in terms of production and reproductive performance. According to Sawa & Bogucki (2010) the length of productive herd-life of cows culled for infertility range from 5.29 to 5.89 years. Strapakova *et al*. (2014) reported that culling risk increases with an increase in age of a cow. The possible reasons for these changes could be disease outbreaks, change in prices and many other socio-economic and genetic changes throughout the cow's productive herd life (Sanders, 2012). It is evident that the significance test for estimates from the model showed that survival differed for different number of days in the productive herd. Similarly, Grohn *et al*. (1997) reported that the hazard of culling differed for different stages of lactation in days.

In Figure 5.2 the estimate of the cumulative hazard curve for productive herd life is presented.

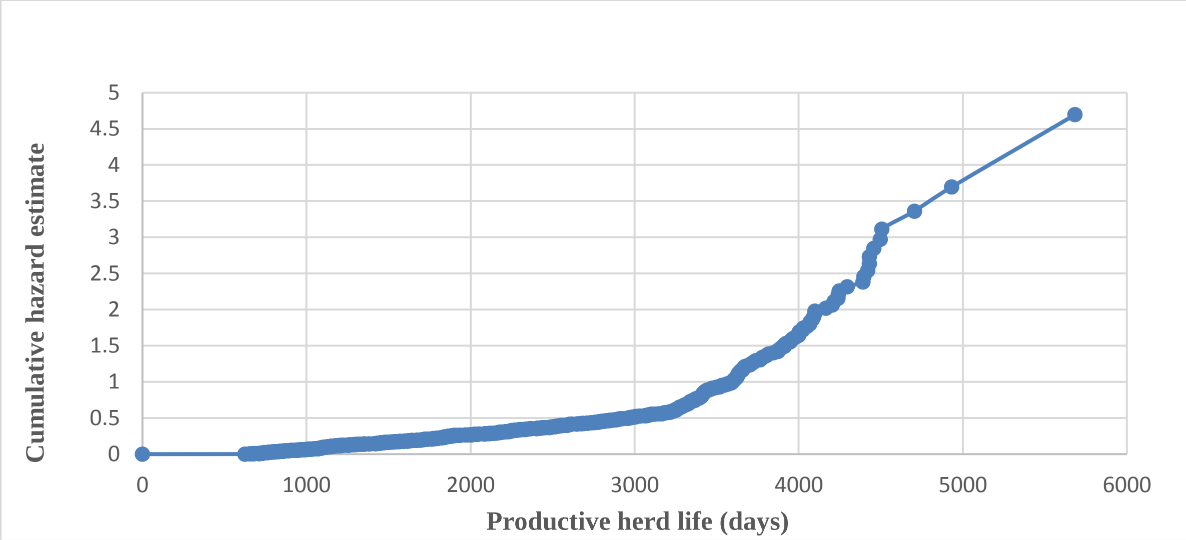

Figure 5.2 Illustrate the cumulative hazard estimate and productive herd life in days.

In Figure 5.2 the cumulative hazard estimate is constant between zero and 1 000 days. The cumulative hazard estimate increases from 1 000 to 3 000 productive herd life days to reach a 0.5 mark. There is a progressive increase in the cumulative hazard estimate from 3 000 to 5 000 productive herd life days. Figure 5.2 shows that the cumulative hazard estimate increases with increasing time (days) in productive herd life. This demonstrates that the culling risk increases with an increase in time the cow spent in the productive herd. For productive herd life of more than 5 000 days the cumulative hazard estimate rises above 4 to 4.5 when approaching 6 000 days of productive herd life length.

In Table 5.3 the culling risk ratios (RR) and standard error (SE) for the effect of year, parity and age at first calving (AFC) stratified into 3 groups (18, 24 and 36 months) are presented.

Table 5.3 The effect of the covariates (year, parity and age at first calving) on the culling risk ratios (RR) in the combined Nguni data set.

Effect	**Class**	**RR**	**SE**	**NUF**
Year	1996	0.009	0.002	4
	1997	0.064	0.371	8
	1998	0.073	0.290	14
	1999	0.053	0.320	11
	2000	0.071	0.280	16
	2001	0.037	0.350	9
	2002	0.069	0.240	22
	2003	0.071	0.250	21
	2004	0.070	0.250	20
	2005	0.064	0.260	18
	2006	0.048	0.290	14
	2007	0.096	0.230	25
	2008	0.082	0.250	20
	2009	0.113	0.210	29
	2010	0.106	0.210	31
	2011	0.107	0.200	35
	2012	0.097	0.210	30
	2013	0.152	0.180	46
	2014	0.224	0.170	52
	2015	1.000	0.000	250
Parity	1	0.008	0.001	3
	2	1.028	0.286	10
	3	4.550	0.270	25
	4	2.540	0.260	68
	5	1.854	0.240	58
	6	0.839	0.240	69
	7	0.662	0.200	42
	8	0.453	0.180	52
	9	1.000	0.000	120
AFC	18	0.061	0.004	8
	24	0.042	0.002	27
	36	1.000	0.001	95

RR = Risk ratio; SE = Standard error; AFC = Age at first calving; NUF = Number of uncensored failures.

The number of uncensored failures (NUF) also refers to the number of cows that were culled from the cow productive herd. The culling risk ratio (RR) and the number of uncensored failures (NUF) were 0.009 and 4 during year 1996. The culling risk ratio increased to 0.073 in year 1997 with 8 uncensored failures in the productive herd. There was a decrease in the culling risk in year 1998, however the number of uncensored failures (NUF) increased to 14 from 8 in the previous year (1997). In the year 1999 the RR was 0.071 and NUF was 11. The culling risk ratio decreased in year 2000 (0.037) and 16 cows were culled from the productive herd. In the year 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010 and 2011 the RR was 0.069, 0.071, 0.070, 0.064, 0.048, 0.096, 0.082, 0.113, 0.106, 0.107 and 0.097, respectively and the NUF was 9, 22, 21, 20, 18, 14, 25, 20, 29, 31 and 35, respectively. The culling risk ratio (RR) progressively increased from the year 2012 to 2015; the RR was 0.152, 0.224, 0.317 and 1.000, respectively during the year 2012, 2013, 2014 and 2015. The number of uncensored failures (NUF) also increased from the year 2012 to 2015; the NUF was 30, 46, 52 and 250, respectively during the year 2012, 2013, 2014 and 2015. South Africa experienced the worst drought in years during the year 2015; as a result most regions were declared drought disaster areas. According to Caraviello *et al*. (2004), Zavadilova *et al*. (2012) and Flynn (2012) environmental factors that have a significant impact on a cow's risk of being culled at any given time may change dramatically on the basis of the prevailing conditions and will most likely change throughout her lifetime rendering the factors time-dependent. Sanders (2012) states that in addition to many other culling reasons, drought is also one important factor that increases culling risk. The variation of risk ratio over the years can be associated with the fact that the culling criterion changes with time (Potocnik *et al*. 2010).

The culling risk ratio (RR) illustrated in Table 5.3 for the effect of parity in productive herd life indicates that cows in their first parity were at a low risk of being culled (RR = 0.008) with only 3 cows culled. However, the culling risk ratio increased from the 2nd to the 3rd parity, the RR was 1.028 and 4.550, respectively for the 2nd and 3rd parity with 10 and 25 cows culled (NUF), respectively. The RR progressively decreased from the 4th parity to the 8th parity; the risk ratio was 2.540, 1.854, 0.839, 0.662 and 0.453, respectively for the 4th, 5th, 6th, 7th, and 8th parity and the NUF was 68, 58, 69, 42 and 52. The culling risk ratio (RR) and the number of uncensored failures (NUF) increased in the 9th parity; the RR and NUF was 1.000 and 120, respectively.

As mentioned earlier, age at first calving (AFC) was stratified into 3 classes; which were 18, 24 and 36 months. The culling risk ratio (RR) was 0.061 for 18 months age at first calving (AFC) and the number of censored failures (NUF) was 8. For 24 months AFC RR and NUF was 0.042 and 27, respectively. The RR and NUF was 1.000 and 95, respectively for the 36 months age at first calving of the cows. Gill & Allaire (1976) recommended ideal age at first calving to avoid culling; they recommended a range from 22.5 to 23.5 months to reach maximum performances. Productive herd life has been reported to decrease with increasing age at first calving (Nilforooshan & Edriss, 2004; Sewalem *et al*., 2005; M'hamdi *et al*., 2010; Zavadilova & Stipkova, 2012). Imbarayarwo-Chikosi (2015) observed that heifers calving for the first time at 24 months of age have a lower risk of being culled than heifers calving for the first time at a very young or very old age, this is in agreement with results obtained in the current study. Strapakova *et al*. (2013) observed an increase in the culling risk ratio in relation to an increase in age at first calving. Similar observations were reported by Ducrocq (1994), Vukasinovic *et al*. (1997), Potocnik *et al*. (2010). The findings are within the range illustrated by Strapakova *et al*. (2013) for Simmental cattle.

5.4 CONCLUSION

The results obtained from the analysis of Nguni cow herd life through use of the Cox model in the Survival kit correspond with various findings in the literature. Therefore, it can be concluded that it is a suitable way to analyse the data. The Kaplan-Meier and the cumulative hazard estimate indicated that the risk of a cow being culled in the productive herd increases with the length of time she is in the productive herd. Culling risk is high for cows calving for the first time at a very young age or at a very old age. Based on the results, it is recommended that heifers calve at 24 months of age for the first time in order to have the lowest risk of being culled from the herd.

CHAPTER 6

GENERAL CONCLUSION AND RECOMMENDATIONS

Productive herd life measures the length of time a female remains in the breeding herd. This trait is influenced by a number of traits of economic importance in beef enterprises, including female fertility. Based on the results from the analysis of productive herd life using ASREML and Survival kit software in this study, low heritability values obtained indicate that it will be difficult to include this trait in most genetic evaluation programs. Findings from the study on use of inter-calving period as a trait to assess cow fertility prove that this trait is not the most suitable selection criteria to be used to improve reproductive performance of beef cows. The Cox model from the Survival kit software, which was used to predict productive herd life, yielded results which indicated that this is a suitable way to analyse the data.

Findings from the current study open doors for more research on traits that affect the Nguni cow's productive herd life, using the Survival kit software. Some other traits and effects that might be of interest for future studies on longevity and fertility in the Nguni cows include: days to calving (DC), days open (DO), calving date with a penalty score (CDP), lactation stage and annual herd size changes. It is unfortunate that the analysis was not extended beyond the 9^{th} parity as there is a big difference in the culling risks between the 8^{th} and 9^{th} parity. This problem was mainly due to constraints of the data set which consisted of only three herds. It is possible that when using the national Nguni data set different results could be obtained and the analysis could be extended beyond the 9^{th} parity.

ABSTRACT

The objective of the study was to assess factors that affect productive herd life and fertility in the Nguni cows using different models. The data set was obtained through the SA Stud book Logix information system. Cattle in the data were registered Nguni cows with their pedigree information from three herds reared extensively in three different environments in South Africa. The raw data included animal identity numbers born between 1968 and 2015, with sire, and sire of sire, dam of sire, dams, sire of dam and dam of dam. One herd had 12 788 animal identity records, the second one had 6 929 and the third one had 8 421 identity records. Amongst other important things included in the original data are the birth dates of each animal, culling date, death date, inspection date, registration date, breeder number, owner number and ownership date. Necessary edits were done to prepare data for analysis.

The age at first calving and inter-calving period were used as traits to assess productive herd life length. Age at first calving was calculated as the difference between birth date and first calving date in days. The inter-calving period was calculated as the difference between two successive birth dates. First analysis was done for productive herd life on the combined data of all three herds using animal models through ASREML program.

For the combined data all effects fitted in the model were significant ($P<0.05$). The mean obtained for age at first calving (AFC) and inter-calving period (ICP) was 893.5 and 408.4 days, respectively. The minimum and maximum age at first calving (AFC) was 512 and 1 099 days, respectively. The minimum and maximum ICP was 313 and 800 days, respectively. The mean, minimum and maximum number of parities (NP) was 7.2 and 15, respectively. Productive herd life (HL) mean and standard deviation was 2 542 and 1 272 days, respectively, with a minimum and maximum of 655 and 6 088 days, respectively. The variance components were 770.7, 2 7196 and 1 103, respectively for additive genetic effects, phenotypic effects and residual and the heritability (h^2) and standard error was 0.028 and 0.04, respectively.

The analysis was also carried out on separate herds using ASREML. The mean for AFC in all three separate herds was 848.1, 893.4 and 918.5 for Komga (KM), Perdeberg (PG) and the Vaalharts (VH) herd, respectively. The minimum AFC was 512, 602 and 534 for KM, PG and VH, respectively and the maximum AFC was 1 099 for all three herds. The mean for inter-calving period (ICP) was in the KM, PG and VH herd was 404.5, 403.5 and 404.2, respectively. The minimum AFC was 329, 315 and 313 in the KM, PG and VH herd. The maximum AFC in the KM, PG and VH herd was 701, 655 and 800, respectively. Variance components for the direct additive effects, phenotypic and residual effects were 19 801, 1 508.2 and 1 743.2, respectively in the KM herd. In the PG herd the variance components were 0.1950, 36 339 and 2 731.4, respectively for the direct additive effects, phenotypic and residual effects. The variance components in the VH herd for direct additive, phenotypic and residual effects were 19 048, 582.98 and 1 220.4, respectively. The heritability estimate was 0.08, 0.00 and 0.03, respectively in the KM, PG and VH herd.

Age at first calving (AFC) and inter-calving period (ICP1 and ICP2), were used as traits to assess cow fertility using linear multiple trait animal models of ASREML and repeatability model. The inter-calving period was used as the repeated trait in the model. The mean for AFC was 896.8. Minimum and maximum age was 512 and 1 230days, respectively. For the first inter-calving period (ICP1) the mean was 423 days, while the minimum and maximum was 270 and 823 days, respectively. The second inter-calving period (ICP2) obtained a mean of 400.3 days, with minimum and maximum of 275 and 810 days, respectively. Variance components for AFC were 6 476.6, 18 238 and 11 762, respectively, respectively for direct additive effects, phenotypic effects and residual and the heritability was 0.36. ICP1 yielded 1 139.8, 10 691 and 9 551.5, respectively for direct additive effects, phenotypic effects and residual with a heritability estimate of 0.11. For ICP2 1 890.1, 8 520 and 6 630.1, respectively were variance components for direct additive effects, phenotypic effects, residual; with a heritability estimate of 0.22. The correlation estimate between AFC and ICP1 was 0.58, and it was 0.59 between AFC and ICP2. ICP1 and ICP2 had a correlation estimate of 0.12 between them. For the repeatability model, the variance component values for ICP used as the repeated trait were 381, 8 155.8 and 7 774.8, respectively for direct additive effects, phenotypic and residual effects. The heritability and repeatability estimate was 0.05 and 0.22, respectively.

The Nguni cow productive herd life was analyzed using the Survival kit V3.12 (Ducrocq & Solkner, 1998) featured models. The Cox model which is the semi-parametric model featured in the Survival kit was used to analyze the Nguni cow data. The Nguni cow herd herd data set analyzed using the Cox model had 1 245 cow records starting from year 1996 to 2015 with parities from one up to the 9th parity. Animal records for cows in the productive herd between the 1st of January 1984 and 31 December 1995 were truncated because of lack of information on the culling or death date. The cow herd was stratified into 3 groups of ages at first calving (18, 24 and 36 months).

This likelihood risk ratio results indicated that year, AFC and parity were significant ($P<0.05$). The model yielded a heritability estimate of 0.02 and a standard error of 0.003. Risk ratios for culling differed for different ages at first calving (18, 24 and 36 months AFC), over the years (from 1996 to 2015) and at different parities (from the 1st to the 9th parity). For 24 months AFC the culling risk ratio was the least compared to 18 and 36 months age at first calving. Heifers that had their first calf at 18 months age were at a 0.061 risk of being culled, whereas the ones that had their first calf at 24 months were at a 0.042 probability of being culled. For heifers that calved for the first time at 36 months age the culling risk ratio was 1.000. In the year 2015 about 250 cows were culled which was more than any other year included in the study. More animals were culled in their 9th (120 cows) and the least number was culled in their first parity (4). Only 4 cows were culled in the group of cows that had their first calf at 18 months, 27 were culled in the group of cows that had their first calf 24 months and 95 were culled in the group that had their first calf at 36 months of age.

Keywords: Nguni cattle, fertility, herd-life, longevity, cow, age at first calving, beef, culling risk.

ISISHWANKATHELO

(Xhosa-native language)

Injongo ngobhalo lwalencwadi ibikuphanda kabanzi ngempawu nezinto ezichaphazela uchumo nobude bobomi kumathokazi enkomo eNguni kumhlambi ekhiqiza inzala, oko kwenziwe kusetyenziswa intlobo ngentlobo zobuchwepheshe be-computer. Ingqokelela yenkcukacha ngazo zonke inkomo ezisetyenziswe koluphando ecishilelwe phantsi ifunyenwe kwa SA Stud book. Inkomo ezifakwa koluphando zinkomo ezibhalisiweyo kumbutho wabafuyi benkomo zeNguni ngokwemigaqo ephunyeleliswe zingcali zolwazi kunye nabafuyi benkomo zohlobo lweNguni, inkcukacha zezinkomo ziquka umnombo ngenzala, abazali, okhokho nezinyanya zenkomo nganye. Ezinkomo zifuyelwe kwifama ezintathu ezikwindawo ezahlukeneyo ezimi kumaphondo amathathu eMzantsi Afrika. Ingqokelela yenkcukacha ngezinkomo iquka inkomo ezizelwe ngonyaka ka 1968 uyotsho ngo 2015, inombolo yesazisi senkomo, utata wayo, utata katata, ukhokho kunye nomama, nomama kamama. Kule mihlambi mithathu omnye ebenenkomo ezi 12 788, owesibini unenkomo ezi 6 929 owesithathu ebenenkomo ezi 8 421. Enye yezinto ebalulekileyo kwinkcukacha zenkomo nganye kuquka omhla wozalwa, umhla wokuchithwa kwenkomo emhlambini okanye umhla wokufa kwayo, umhla wobhaliswa kwayo, inombolo yomnikazi wayo kunye nomhla wokungena kwayo emhlambini womnini wayo lowo. Lwenziwe ke uhlengahlengiso ukulungisa zonke ezinkcukacha khona ukuze zikulungele ufakwa kuchwepheshe nobugcisa be-computer.

Ubudala bamathokazi ngelixa eqala uzala kunye nexesha phakathi kwenzala yethokazi ngalinye zisetyenziswa ukujonga ubude bobomi bamathokazi esemhlambini ekhiqiza inzala. Ubudala bamathokazi ngelixa eqala ukuzala bubalwe ngokuthi kubalwe intsuku usukela kumhla wozalwa uyotsho kumhla wozalwa wenkonyane lokuqala lwethokazi ngalinye. Kanti lona ixesha phakathi kwenzala libalwe ngokwentsuku phakathi kwemihla yozalo

lwamankonyane amabini azalwe elekelana. Uvavanyo lokuqala lwenziwe kwingqokelela yenkcukacha zemihlambi yomithathu idityanisiwe kujongwa ubude bobomi bamathokazi ekhiqiza inzala, koluvavanyo kusetyenziswe ubugcisa be-computer obubizwa nge ASREML.

Kuvavanyo apho ingqokelela yenkcukacha zemihlambi yomithathu idityanisiweyo, ubudala bamathokazi ngelixa eqala ukuba namakonyanye kunye nexesha phakathi kokwelekelana kwenzala kubenefuthe ($P<0.05$) kubude kobomi bamathokazi esemhlambini ekhiqiza inzala. Ubudala ngelixa amathokazi eqala uzala kwimihlambi yomithathu idityanisiwe ibizintsuku ezi 893.5, kanti ixesha phakathi kokwelekelana kwenzala yethokazi ngalinye ibizintsuku ezi 408.4. Eyona nzala encinane phakathi kwalomhlambi wamthokazi edityanisiwe ibi 7.2 kanti eninzi ibi 15. Ubude bobomi bamathokzi esemhlambini ekhiqiza inzala ibizintsuku ezi 2 542, ezontsuku zininzi zi 6 088 kanti obona bom obebubufutshane ibizintsuku ezi 655. Imfuzo ibi 0.028.

Lwenziwe uvavanyo nakwimihlambi yomithathu yohlulwahluliwe kukwasetyenziswa i-ASREML. Iziphumo ziveze ukuba ubudala bamathokazi ngelixa eqala ukuzala ibizintsuku ezi 848.1, 893.4 kunye 918.5 kumhlambi ka Komga(KM), zase Perdeberg (PG) kunye nowase-Vaalharts (VH). Kanti ixesha phakathi kokwelekelana kwenzala yethokazi ngalinye ibizintsuku ezi 404.5, 403.5 kunye nezi 404.3 kumhlambi wase KM, PG kunye no VH. Imfuzo kumhlambi ka KM, no PG kunye no VH ibi 0.08, 0.00 kunye ne 0.03.

Kuphinde kwasetyenziswa ubudala ngelixa ithokazi ngalinye liqala uzala kunye nexesha phakathi kwenzala eyolekelanayo ujonga impawu ezinefuthe kuchumo lwamathokazi enkomo. Nalapha kusetyenziswe hlobo luthile lobuchwepheshe be-computer nobugcisa be-ASREML. Iziphumo zovavanyo ziveze ukuba amathokazi aqala uzala enentsuku ezi 896.8 koluvavanyo. Kanti intsuku phakathi kwamankonyane alekelanayo ibezintsuku ezi 423. Iziphumo zibonakalise ukuba awona mathokazi azala emancinane azala enentsuku ezi 512, kanti azala emadala wona azala enentsuku ezi 1 230. Imfuzo ibi 0.05. Zombini ezimpawu ziqukwe koluphando zibenefuthe (P<0.05) kuchumo lwamathokazi.

Kuphinde kwenziwa uvavanyo ukujonga ubude bobomi bamathokazi enkomo zeNguni esemhlambini ekhiqiza inzala kusetyenziswa ubuchwepheshe be-Survival kit V3.12 (Ducrocq & Solkner, 1998). Pha kwi Survival kit kuye kwachongwa ubugcisa obubizwa nge Cox model ukuze kwenziwe uvavanyo kwingqokelela yenkcukacha zomhlambi wonke wamathokazi eNguni achongwe koluphando. Lomhlambi wamathokazi eNguni ubunenkcukacha zenkomo ezi 1 245 ezicishilelwe usukela ngonyaka 1996 uyotsho ngo 2015, ucishilelo olu luquka inzala yokuqala uyotsho kweyethoba. Lomhlambi wamathokazi uye wohlulwa kathathu esohlulwa ngokwenyanga ubudala ekuzaleni ithole lokuqala (ukutsho ke ibiliqela lamathokazi aqale uzala enenyanga ezi 18, ezi 24 kunye nezi 36).

Kwezinziwe uvavanyo olubonisa amathuba wokuba amathokazi asebungciphekweni kangakanani okuba achithwe emhlambini. Iziphumo zibonise ukuba unyaka kunye nobudala bethokazi ngelixa liqala ubanenkonyane zinefuthe (P<0.05) koluvavanyo. Kanti sona isigaba zenzalo khange sibenefuthe koluvavanyo. Imfuzo efunyenwe kweluvavanyo ibe 0.02. Amathuba wokuba sebungciphekweni okuba amathokazi athile achithwe emhlambini abonakalise ungalingani ngokwehlukahlukana kobudala bamathokazi ngelixa eqala uzala (anenyanga ezi 18, ezi 24 kunye nezi 36). Nasekwahlukahlukeni kweminyaka (usukela kunyaka 1996 uyotsho kunyaka 2015) kunye nesigaba senzala (usekela kwinzala yokuqala uyotsho kweyethoba) yethokazi okanye imazi nganye umahluko ububonakala. Amathokazi aqale uzala enenyanga ezi 24 abonakalise ungabikho sebungciphekweni kakhulu bokuchithwa emhlambini xa ethelekiswa namathokazi aqale uzala enenyanga ezi 18 kunye naqale enezi 36. Amathokazi aqale uzala enenyanga ezi 18 ebesebungciphekweni obulinganiselwa ku 0.061, kanti wona aqale uzala enanyanga ezi 24 ebesebngciphekweni obulinganiselwa ku 0.042. Kanti wona aqale uzala enenyanga ezi 36 ebesebungciphekweni obulinganiselwa ku 1.000. Iziphumo zoluvavanyo zibonise ukuba inkomo ezininzi zichithiwe emhlambini ngonyaka ka 2015 inani lazo liqikelelwa ku 250 eli linani elikhulu ukwedlula nawuphi na unyaka kuleminyaka ibalulwe koluphando. Xa kujongwa kwisigaba senzalo yezi mazi namathokazi kubonakele ukuba uninzi lwenkomo luchithwe xa likwisigaba sethoba kwinzala (inkomo ezilinganiselwa ku 120). Kwinkomo ezikwisigaba sokuqala ezisaqala uzala kuchithwe inkomo ezine kuphele, esisigaba sesona sinenkomo ezimbalwa ezichithiweyo kunazo zonke izigaba zenzalo.

REFERENCES

Acocks, J.P.H., 1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa No. 57.

Ahlman, T., Berglund, B., Rydhmer, L. & Strandberg, E., 2010. Culling reasons in organic and conventional dairy herds and genotype by environment interaction for longevity. J. Dairy Sci. 94: 1568-1575.

Allaire, F.R. & Gibson, J.P., 1992. Genetic value of herd life adjusted for milk production, J. Dairy Sci. 75: 49-56.

Amimo, J.O., Mosi, R.O., Wakhungu, J.W., Muasya, T.K. & Inyangala, B.O., 2006. Phenotypic and genetic parameters for Ayrshire cattle on large-scale farms in Kenya. Livestock Research for Rural Development, 18 (10).

Ansari-Lari, M., Rezagholi, M. & Reiszadeh, M., 2009. Trends in calving age and calving intervals for Iranian Holstein in Fars province, Southern Iran. Tropical Animal Health Production, 41: 1283-1288.

Arthur, P.F., Makarechian, M., Berg, R.T. & Weingardt, R., 1993. Longevity and lifetime productivity of cows in a purebred Hereford and two multibreed synthetic groups under range conditions. J. Anim. Sci. 71:1142-1147.

Baliero, E., De Silva, S., Carneiro, G.G. & Salvo, A.E.W., 1981. Reproductive efficiency in a herd of Guzerat dairy cows. 2. Calving interval. Arquivos da Escola de Veterinaria, Universidade Federal de Minas Gerais. 33: 489-495 (Animal Breeding Abstracts 50: 5492).

Banga, C.B., Neser, F.W.C. & Garrick, D.J., 2014. Breeding objectives for Holstein in South Africa. S. Afr. J. Anim. Sci. 44(3).

Basu, S.B., Bhatnagar, D.S. & Taneja, V.K., 1983. Genetic and phenotypic parameters of lifetime traits in Tharparkar cows. Indian J. Dairy Sci. 36: 207-210.

Baumung, R., Solkner, J., Gierzinger, E. & Willam, A., 2001. Ecological total merit index for an Austrian dual purpose cattle breed. Arch Tierz. 44: 5-13.

Beaudeau, F., Seegers, H., Ducrocq, V., Fourichon, C. & Bareille, N., 2000. Effect of health disorders on culling in dairy cows: a review and critical discussion. Ann. Zootech. (Paris) 49:293-311.

Bester, J., Matjuda, E., Rust, J.M. & Fourie, H.J., 2003. The Nguni: a case study In: FAO Community-based management of animal genetic resources - proceedings of the workshop held in Mbabane, Swaziland 7-11 May 2001. Rome: UNDP, GTZ, CTA, FAO. 45-68.

Bielfeldt, J.C., Tolle, K. H., Badertscher, R. & Krieter J., 2006. Longevity of Swiss Brown cattle in different housing systems in Switzerland. Livest. Sci. 101: 134-141.

Boldman, K.G., Freeman, A.E., Harris, B.L. & Kuck, A.L., 1992. Prediction of sire transmitting abilities for herd life from transmitting abilities for linear type traits. J. Dairy Sci. 75: 552-563.

Bourdon, R.M. & Brinks, J.S., 1983. Calving date versus calving interval as a reproductive measure in beef cattle. J. Anim. Sci. 57: 1412-1417.

Bouska, J., Stipkova M., Krejcova, M. & Barton, L., 2007. The effect of growth and development intensity in replacement heifers on economically important traits of Holstein cattle in the Czech Republic. Czech J. Anim. Sci. 52: 277-83.

Brotherstone, S., Veerkamp, R.F. & Hill, W.G., 1997. Genetic parameters for a simple predictor of the lifespan of Holstein-Friesian dairy cattle and its relationship to production. J. Dairy Sci. 65: 31-37.

Brzakova, M., Svitakova, A., Vesela, Z. & Citek, J., 2016. Genetic parameters for first calving interval in beef cattle. Acta. Fytotechn. Zootechn. 19: 22-24.

Buenger, A., Ducrocq, V. & Swalve, H.H., 2001. Analysis of survival in dairy cows with supplementary data on type scores and housing systems from a region of Northwest Germany. J. Dairy Sci. 84: 1531-1541.

Burke, B.P. & Funk, D.A., 1993. Relationship of linear type traits and herd life under different management systems. J. Dairy Sci. 76: 2773-2782.

Burris, M.J. & Priode, B.M., 1958. Effect of calving date on subsequent calving performance. J. Anim. Sci. 17: 527-533.

Burnside, E.D. & Wilton, J.W., 1970. Anatomical traits as they relate to productive utility. J. Dairy Sci. 53: 837-846.

Campos, R.V., Cobuci, J.A., Costa, C.N. & Neto, J.B., 2012. Genetic parameters for type traits in Holstein cows in Brazil. Revista Brasileira de Zootecnia. 41: 2150-2161.

Caraviello, D.Z., Weigel, K.L. & Gianola, D., 2004. Prediction of longevity breeding values for US Holstein sires using survival analysis methodology. J. Dairy Sci. 87: 3518-3525.

Chookani, A., Dadpasand, M., Mirzaei, H.R., Rokouii, M. & SayadNezhad, M.B., 2010. An estimation of genetic parameters for some reproductive traits and their relationships to milk yield in Iranian Holstein cattle. Iranian J. Anim. Sci. 40(4): 53-61.

Cruickshank, J., Weigel, K.A., Dentine, M.R. & Kirkpatrik, B.W., 2002. Indirect prediction of herd life in Guernsey cattle. J. Dairy Sci. 85: 1307-1313.

Cushman, R.A., Kill, L.K., Funston, R.N., Mousel, E.M. & Perry, G.A., 2013. Heifer calving date positively influences calf weaning weights through six parturitions. J. Anim. Sci. 91: 4486-4491.

Daliri, Z., Hafezian, S.H., Shadparvar, A. & Rahimi, G., 2008. Genetic relationships among longevity, milk production and linear type traits in Iranian Holstein Cattle. J. Anim. & Vet. Advances. 7: 512-515.

Dalstead, N.L. & Gutierrez, P.H., 1989. How long do you keep her? Beef Minneapolis, MN. Spring 1989. 15.

Dechow, C.D., Rogers, G.W., Klei, L. & Lawlor, T.J., 2003. Heritabilities and correlations among body condition score, dairy form and selected linear type traits. J. Dairy Sci. 86: 2236-2242.

Dekkers, J.C.M., Jairath, L.K. & Lawrence, B.H., 1994. Relationships between sire genetic evaluations for conformation and functional herd life of daughters. J. Dairy Sci. 77: 844-854.

De Kruif, A., 1978. Factors influencing the fertility of a cattle population. J. Reprod. Fert. 54: 507-518.

Dentine, M.R., McDaniel, B.T. & Norman, H.D., 1987. Evaluation of sires for traits associated with herd life of grade and registered Holstein cattle. J. Dairy Sci. 70: 2623-2634.

Deutscher, G.H., Stotts, J.A. & Nielsen, M.K., 1991. Effects of breeding season length and calving season on range beef cow productivity. J. Anim. Sci. 69: 3453-3460.

De Vaccaro, L., Garcia, M., Bazan, O. & Bardales, E., 1977. Fertility and body weight at first mating of zebu cattle grazing cleared jungle land in the Amazon. Tropical Agriculture (Trinidad). 54: 223-227.

De Vries, A., Olson, J.D. & Pinedo, P.J., 2010. Reproductive risk factors for culling and productive life in large dairy herds in the eastern United States between 2001 and 2006. J. Dairy Sci. 93: 613-623.

Dhoke, M.V. & Johar, K.J., 1977. Variations in calving interval of Haryana cows. Indian Vet. J., 54: 619-622.

Diskin, M.G. & Kenny, D.A., 2014. Optimising reproductive performance of beef cows and replacement heifers. J. Anim. Sci. 8: 27-39.

Djordjevic, V. & Lepojevic, V., 2003. Henderson's approach to variance components estimation for unbalanced data. Facta Universitatis, Series: Economics and Organization, 2: 59-64.

Do, C., Wasana, N., Cho, K., Choi, Y., Choi, T., Park, B. & Lee, D., 2013. The effect of age at first calving and calving interval on productive life and lifetime profit in Korean Holsteins. Asian Australas J. Anim. Sci. 11: 1511-1517.

Duarte, F.A.M, Valle, A., Lobo, R.B. & Bezerra, L., 1983. Phenotype and genetic study in reproductive and production characters in the Pitanguieras breed. 2. Calving interval. Agronomia Tropical (Maracay, Venezuela), 30: 325-334.

Ducrocq, V., Quaas, R.L., Pollak, E.J. & Casella, G., 1988. Length of productive life of dairy cows. 1. Justification of a Weibull model. J. Dairy Sci. 71: 3061-3070.

Ducrocq, V., 1994. Statistical analysis of length of productive life for dairy cows of the Normande breed. J. Dairy Sci. 77: 855-866.

Ducrocq, V. & Solkner, J.,1998. The Survival Kit-V3.0, a package for large analyses of survival data. In: 6th World Cong. Genet. Appl. Livest. Prod. 27: 447-448.

Durr, J.W., Monardes, H.G. & Cue, R.I., 1999. Genetic analysis of herd life in Quebec Holsteins using Weibull models. J. Dairy Sci. 82: 2503-2513.

Du Toit, J., Van Wyk, J.B. & Maiwashe, A., 2009. Genetic parameter estimates for functional herd life for the South African Jersey breed using a multiple trait linear model. S. Afr. J. Anim. Sci. 39: 40-44.

Du Toit, J., Van Wyk, J.B. & Maiwashe, A., 2012. Correlated response in longevity from direct selection for population in the South African Jersey breed. S. Afri. Anim. Sci. 42: 18-25.

Els, D.L., 1988. Kruisteling vir vleisproduksie. PhD Thesis, University of the Free State, South Africa.

Endicott, R.L., Funston, R.N., Mulliniks, J.T. & Roberts, A.J., 2013. Implications of beef heifer development systems and lifetime productivity. J. Anim. Sci. 91: 1329-1335.

Enyew, N., Branang, E. & Rottmann, O.J., 2000. Reproductive performance and herd life of crossbred dairy cattle with different levels of European inheritance in Ethiopia. Livestock production and the environment: implication for livelihoods. Proceedings of the 7th annual conference of the Ethiopian Society of Animal Production (ESAP). 26-27 May 1999, Addis Ababa, Ethiopia.

Essl, A., 1998. Longevity in dairy cattle breeding: a review. Livest. Prod. Sci. 57:79-89.

Esslemont, R.J., 1974. Economic and husbandry aspects of the manifestation and detection of oestrus in cows. Part I. Economic aspects. ADAS Q. Rev. 12: 175-184.

Everitt, B.S. & Hothorn, T., 2006. A handbook of Statistical Analyses using R, Chapman & Hall/CRC. 146-148.

Faraji-Arough, H., Aslaminejad, A.A. & Farhangfar, H., 2011. Estimation of genetic parameters and trends for age at first calving and calving interval in Iranian Holstein cows. Journal of Research in Agricultural Science, 7(1): 79-87.

Farhangfar, H. & Naeemipour Younesi, H., 2007. Estimation of genetic and phenotypic parameters for production and reproduction traits in Iranian Holsteins. Journal of Science and Technology of Agriculture and Natural Resources-Water and Soil Science, 11(1): 431-441.

Fetrow J., Nordlund, K.V. & Norman, H.D., 2006. Invited review: Culling: nomenclature, definitions, and recommendations. J. Dairy Sci. 89: 1896-1905.

Flynn, R., 2012. Approaches for data analysis: Survival analysis. J. Clin. Nurs., 21: 2789-2797.

Forabosco, F., Groen, A.F., Bozzi, R., Van Arendonk, J.A.M., Filippini, F., Boettcher, P. & Bijma, P., 2004. Phenotypic relationships between longevity, type traits and production in Chianina beef cattle. J. Anim. Sci. 82: 1572-1580.

Forabosco, F., 2005. Breeding for longevity in Italian Chianina cattle. MSc Thesis. Wageningen, Netherlands.

Frazier, E.L., Sprott, L.R., Sanders, J.O., Dahm, P.F., Crouch, J.R. & Turner, J.W., 1999. Sire marbling score expected progeny difference and weaning weight maternal expected progeny difference associations with age at calving and calving interval in Angus beef cattle. J. Anim. Sci. 77:1322-1328.

Garcia, D.A., Carreno, L.O.D., Ono, R.K., Pires, M.P., Farah, M.M., Ventura, H.T., Millen, D.D. & Fonseca, R., 2015. Estimates of genetic parameters for reproductive traits in Brahman cattle breed. J. Anim. Sci. 93: 3287-3291.

Ghiasi, H., Pakdel, A., Javaremi, A.N., Mehrabani, H.Y., Yeganeh, M., Honarvar, O., Gonzalez-Recio, M., Jesus, C. & Alenda, R., 2011. Genetic variance components for female fertility in Iranian Holstein cows. Livest. Sci. 139(3): 277-280.

Gill, G.S. & Allaire, F.R., 1976. Relationship of age at first calving, days open, days dry, and herdlife to a profit function of dairy cattle. J. Dairy Sci. 59 (6): 1131-1139.

Gilmour, A.R., Cullis, B. R. & Verbyla, A. P., 1997. Accounting for natural and extraneous variation in the analysis of field experiments. J. Agric. Biol. Environ. Stat., 2: 269-293.

Goshu, G. & Hegde, B.P., 2003. Age at first calving, calving interval and milk yield performance of Friesian-Boran crossbred cattle at Cheffa state farm, Wollo, Ethiopia. Bull. Anim. Health Prod. Afr., 51: 190-197.

Goshu, G., 2005. Breeding efficiency, lifetime lactation and calving performance of Friesian-Boran crossbred cows at Cheffa farm, Ethiopia. Livestock Research for Rural Development, 17(7): 33-35.

Goyache, F. & Gutierrez, J.P., 2001. Heritability of reproductive traits in Asturiana de los Valles beef cattle breed. Arch. Tierz. Sci. 68: 489-496.

Grobler, S.M., Scholtz, M.M., Schwalbach, L.M.J. & Greyling, J.P.C., 2013. Effect of synchronisation on calving date following natural mating in beef cattle. Appl. Anim. Husb. Rural Dev. 6: 15-17.

Grobler, S.M., 2016. Alternative management systems to increase to beef production under extensive conditions. PhD Thesis. University of the Free State, Bloemfontein, South Africa.

Grohn, Y.T., Eicker, S.W., Ducrocq, V. & Hertl, J.A., 1997. Effect of diseases on the culling of Holstein dairy cows in New York State. J. Dairy Sci. 81: 966-978.

Haile-Mariam, M. & Kassa-Mersha, H., 1994. Genetic and environmental effects on age at first calving and calving interval of naturally bred Boran (zebu) cows in Ethiopia. Anim. Prod. 58: 329-334.

Haile-Mariam, M., Morton, J. M. & Goddard, M.E., 2003. Estimates of genetic parameters for fertility traits of Australian Holstein-Friesian cattle. J. Anim. Sci. 76: 35-42.

Hamann, H. & Distl, O., 2002. Prediction of functional longevity for dairy cows by using foot quality traits in German holstein bulls. In: 7th World Congress on Genetics Applied to Livestock Production, 19-23 August, Montpellier, France.

Hanotte, O., Okomo, M., Bradly, Verjee, Y., Ochieng, A., Teale, A. & Rege, J.E.O., 1998. Geographical distribution and frequency of taurine Bos Taurus and zebu B. indicus Y chromosome haplotypes amongst sub-saharan African cattle breeds. Proc. 4th Global Conf. on Conversation Domestic Animal Genetic Resources, Nepal, 17-21 August.

Hansen, L.B., Cole, J.B., Marx, G.D. & Seykora, A.J., 1999. Productive life and reasons for disposal of Holstein cows selected for large versus small body size. J. Dairy Sci. 82: 795-801.

Hare, E., Norman, H.D. & Wright, J.R., 2006. Trends in Calving Ages and Calving Intervals for Dairy Cattle Breeds in the United States. J Dairy Sci. 89:365-370.

Hermas, S.A. & Young, C.W., 1987. Genetic relationships and additive genetic variation in productive and reproductive traits in Guernsey dairy cattle. J. Dairy Sci. 70: 1252-1257.

Hinojosa, A., Franco, A. & Bolio, I., 1980. Genetic and environmental factors affecting calving interval in a commercial beef herd in a semi-humid tropical environment. Tropical Animal Production, 5: 165-171.

Hofmeyr, J.H., 1994. Findings of a committee on a gene bank for Livestock. Proc. Conf. Conversation Early Domesticated Animals of Southern Africa, Pretoria, 3-4 March 1994.

Hoque, M. & Hodges, J., 1980. Genetic and phenotypic parameters of lifetime production traits in Holstein cows. J. Dairy Sci. 63: 1900-1910.

Hultgren, J. & Svensson, C., 2010. Calving Interval in Dairy Cows in Relation to Heifer Rearing Conditions in Southwest Sweden. Reproduction Domestick Animal, 45: 136-141.

Imbarayarwo-Chikosi, V.E., 2015. Genetic evaluation of functional longevity in South African Holstein cattle using a proportional hazard model. PhD Thesis, University of Stellenbosch, South Africa.

Jairath, L.K., Hayes, J.F. & Cue, R.I., 1994. Multi-trait restricted maximum likelihood estimates of genetic and phenotypic parameters of lifetime performance traits for Canadian Holsteins. J. Dairy Sci. 77: 303-312.

Jenko, J., Ducrocq, V. & Kovac, M., 2013. Comparison of piecewise Weibull baseline survival models for estimation of true and functional longevity in Brown cattle raised in small herds. J. Anim. Sci. 7:10: 1583-1591.

Johnston, D.J. & Bunter, K.L., 1996. Days to calving in Angus cattle: Genetic and environmental effects, and covariances with other traits. Livest. Prod. Sci. 45: 13-22.

Kadarmideen, H.N., Thompson, R., Coffey, M.P. & Kossaibati, M.A., 2003. Genetic parameters and evaluations from single-and multiple-trait analysis of dairy cow fertility and milk production. Livest. Prod. Sci. 81: 183-195.

Kars, A.A., Erasmus, G.J. & van der Westhuizen, J., 1994. Variance compomnents and heritability estimates for growth traits in the Nguni stud at Bartlow Combine. S. Afr. J. Anim. Sci. 24(4).

Klosterman, E.W., 1981. Measuring beef production in the cow herd. S. Afr. J. Anim. Sci. 11: 195-198.

Kluyts, J.F., Neser, F.W.C. & Bradfield, M.J., 2003. Development of breeding objectives for beef cattle breeding: Derivation of economic values. S. Afr. J. Anim. Sci. 33(3): 11-13.

Koots, K.R., Gibson, J.P. & Wilton, J.W., 1994. Analyses of published genetic parameters estimates for beef production traits. 1. Heritability. Anim. Breed. Abst. 62: 309.

Kumar, S. & Bhat, P.N., 1979. Reproductive performance of Hariana cattle. Indian J. Anim. Sci. 49: 1001-1008.

Lake, M.C., 2003. Soil classification. A global desk reference. Print ISBN: 978-0-8493-1339-4 CRC Press.

Larroque, H., & Ducrocq, V., 1999. An indirect approach for the estimation of genetic correlations between longevity and other traits. In: Proc. 4th International Workshop on Genetic Improvement of Functional Traits in Cattle. Interbull Bulletin, 21, Jouy-en-Josas, France, 128-135.

Lopes, G., Giordano, J., Valenza, A., Herlihy, M.M., Guenther, J.N., Wiltbank, M.C., & Fricke, P.M., 2013. Effect of timing of initiation of resynchronization and presynchronization with gonadotropin-releasing hormone on fertility of resynchronized inseminations in lactating dairy cows. J. Dairy Sci. 96: 3788-3798.

Lopez de Torre, G. & Brinks, J.S., 1990. Some alternatives to calving date and interval as measures of fertility in beef cattle. J. Anim. Sci. 68: 2650.

Lopez-Villalobos, N. & Garrick, D.J., 2005. Methodology for the design and enhancement of genetic improvement programs illustrated in the context of the New Zealand dairy industry. Agrociencia IX, 553-568.

Louca, A. & Legates, J.E., 1968. Production losses in cattle due to days open. J. Dairy Sci. 51: 573-583.

Lubbers, R., Brotherstone, S., Ducrocq, V.P., & Visscher, P.M., 2000. A comparison of a linear and proportional hazards approach to analyze discrete longevity data in dairy cows. Animal Science, 70: 197-206.

MacGregor, R.G. & Casey, N.H., 1999. Evaluation of calving interval and calving date as measures of reproductive performance in a beef herd. Livest. Prod. Sci. 57: 181-191.

Maciel, S., Amimo, J., Martins, M., Okeyo, A.M., Scholtz, M.M. & Neser, F.W.C., 2013. Feedlot performance of the Nguni ecotypes in southern Mozambique. Livestock Research for Rural Development, 25(6).

Maddala, G.S., 1983. Limited-dependent and quantitative variables in econometrics Cambridge Univ. Press, UK.

Maiwashe, A., Nephawe, K.A. & Theron, H.E., 2009. Analysis of stayability in South African Angus cattle using a threshold model. S. Afr. J. Anim. Sci. 39(1).

Makina, S.O., Whitacre, L.K., Decker, J.E., Taylor, J.F., MacNeil, M.D., Scholtz, M.M., Marle-Koster, E.V., Muchadeyi, F.C., Makgahlela, M.L. & Maiwashe, A., 2016. Insight into the genetic composition of South African Sanga cattle using SNP data from cattle breeds worldwide. Genet. Sel. Evol. 48: 88.

Makgahlela, M.L., Banga, C.B., Norris, D., Dzama, K. & Ngambi, J.W., 2008. Genetic analysis of age at first calving and calving interval in South African Holstein cattle. Asian Journal of Animal and Veterinary Advance, 3(4): 197-205.

Martinez, G.E., Koch, R.M., Cundiff, L.V., Gregory, K.E. & van Vleck, L.D., 2004. Genetic parameters for six measures of length of productive life and three measures of lifetime production by 6yr after first calving for Hereford cows. J. Anim. Sci. 82: 1912-1918.

Mathews, K.H.J. & Short, S.D., 2001. The beef cow replacement decision. J. Agrib. 191-211.

Matjuda, E.L., 2012. Developing breeding objectives for the Nguni cattle breed in South Africa. PhD Thesis. Faculty of Science and Agriculture, Department of Agricultural Economics and Animal Production. University of Limpopo, South Africa.

McCampbell, C.W., 1921. The effect of early breeding upon range cows. J. Anim. Sci. 19(21): 12-14.

Meacham, N.S. & Notter, D.R., 1987. Heritability estimates for calving date in Simmental cattle. J. Anim. Sci. 64: 701-705.

Melaku, N., 1994, Reproductive performance of a Holstein-Friesian dairy cattle herd at Holeta, Shoa, Ethiopia. MSc Thesis. Alemaya University of Agriculture, Dire Dawa, Ethiopia.

Melton, B.E., 1980. Economics of beef cow culling and replacement decisions under genetic progress. Western Journal of Agricultural Economics, 5: 137-147.

Mercadante, M.E.Z., Lobo, R.B. & Oliveira, H.N., 2000. Estimativas de (co)variâncias entre características de reprodução e de crescimento em fêmeas de um rebanho Nelore. (In Portuguese.) R. Bras. Zootec. 29:997-1004.

Meszaros, G., Wolf, J. & Kadlecik, K., 2008. Factors affecting the functional length of productive life in Slovak Pinzgau cows. Czech J. Anim. Sci. 53 (3): 91-97.

Meyer, K., Hammond, K., Parnell, P.F., Mackinnon, M.J. & Sivarajasingam, S., 1990. Estimates of heritability and repeatability for reproductive traits in Australian beef cattle. Livest. Prod. Sci. 25: 15-30.

M'hamdi, N., Aloulou, R., Bouallegue, M., Brar, S.K. & Hamouda, M.B., 2010. Study on functional longevity of Tunisian Holstein dairy cattle using a Weibull proportional hazards model. Livest. Sci. 132: 173-176.

Miglior, F., van Doormaal, B. & Kistemaker, G., 2001. Prediction of direct herd life proofs. Technical report to the Canadian Genetic Evaluation Board, April 2001, St. Hyacinthe, Quebec, Canada.

Montoni, D., Manrique, U., Sabino, L., Bastidas, J. & Garcia, E., 1981. Reproductive performance in a herd of Gir and zebu cows in Venezuela. 1. Calving interval. Memoria, Asociacion Latinoamericana de Produccion Animal, 16: 120 (Animal Breeding Abstracts). 52: 6513.

Morris, C.A., 1980. A review of relationships between aspects of reproduction in beef heifers and their lifetime production: 1. Associations with fertility in the first joining season and with age at first joining. Anim. Breed. Abstr. 48: 655-675.

Mostert, B.E., Theron, H.E & Kanfer, F.H.J. 2006. Test-day model for South African for participation in the international evaluations. S. Afr. J. Anim. Sci. 36: 5870.

Mousel, E.M., Cushman, R.A., Perry, G.A. & Kill, L.K., 2012. Efffect of heifer calving date on longevity and lifetime productivity. Proceedings, Applied Reproductive Strategies in Beef Cattle. December. December 3-4. 2012, Sioux Fall, SD.

Najafabadi, H.A., Mahyari, S.A., Edriss, M.A. & Strapakova, E., 2016. Genetc analysis of productive life length in Holstein dairy cows using Weubull proportional risk model. Arch. Anim. Breed. 59: 387-393.

Neser, F.W.C., van Wyk, J.B. & Scholtz, M.M., 2014. Evaluation of cytoplasmic genetic effects for production and reproduction traits in Afrikaner cattle. S. Afr. J. Anim. Sci. 44(5).

Nguni Cattle Breeders Society, 2008. The breed from the past for the future. P.O. BOX 506, Bloemfontein, 9300.

Nilforooshan, M.A. & Edriss, M.A., 2004. Effect of age at first calving on some productive and longevity traits in Iranian Holsteins of the Isfahan Province. J. Dairy Sci. 87: 2130-2135.

Nodot, P., Olson, T., Koger, M. & Hargove, D., 1981. Reproductive performance of IndoBrazilian cows in Mexico. Memoria, Asociacion Latinoamericana de Produccion Animal, 16: 145-146.

Odhiambo, J.F., Rhinehart, D.J., Helmondollar, R., Pritchard, J.Y, Osborne, P.I., Felton E.E. & Dailey, R.A., 2009. Effect of weaning regimen on energy profiles and reproductive performance of beef cows. J. Anim. Sci. 87: 2428-2436.

Ojango, J.M.K. & Pollott, G.E., 2001. Genetics of milk yield and fertility traits in Holstein-Friesian cattle on large-scale Kenyan farms. J. Anim. Sci. 79: 1742-1750.

Olori, V.E., Pool, M.H., Calus, M.P.L., Cromie, A.R. & Veerkamp, R.F., 2003. Joint evaluation of survival and fertility in dairy cattle with a linear model. Interbull Bulletin 30: 20-24.

Oyama, K., Mukai, F. & Yoshimura, T., 1996. Genetic relationships among traits recorded at registry judgment, reproductive traits of breeding females and carcass traits of fattening animals in Japanese Black cattle. Anim. Sci. Technol. 67: 511-518.

Oyama, K., Katsuta, T., Anada, K. & Mukai, F., 2002. Heritability and repeatability estimates for reproductive traits of Japanese Black cows. Asian-Aust. J. Anim. Sci. 15(12): 1680-1685.

Oyedipe, E.O., Osori, D.I.K., Akerejola, O. & Saror, D., 1982. Effect of level of nutrition on onset of puberty and conception rates of zebu heifers. Theriogenology. 18: 525-539.

Pachova, E., Zavadilova, L. & Solkner, J., 2005. Genetic evaluation of the length of productive life in Holstein cattle in the Czech Republic. Czech J. Anim. Sci. 50: 493-498.

Panetto, J.C.C., Gutierrez, J.P., Ferraz, J.B.S., Cunha, D.G. & Golden, B.L., 2010. Assessment of inbreeding depression in a Guzerat dairy herd: Effects of individual increase in inbreeding coefficients on production and reproduction. J. Dairy Sci. 93: 4902-4912.

Parish, J., 2010. Beef production strategies: Beef cow longevity. Mississipi State University, USA.

Parmar, S.N.S. & Johar, K.S., 1982. Factors affecting calving interval in Tharparkar cows. Indian Veterinary Medical Journal 6: 83-86.

Patterson, D.J., Perry, R.C., Kiracofe, G.H., Bellows, R.A., Staigmiller, R.B. &. Corah, L.R., 1992. Management considerations in heifer development and puberty. J. Anim Sci. 70: 4018-4035.

Perry, G.A., Perry, B.L. & Roberts, C.A., 2011. Estrous response following the PG 6-d CIDR protocol for heifer that do and do not exhibit estrus prior to CIDR insertion and its usefulness as a fixed-time AI protocol. In: Proc. Western Sect. Am. Soc. Anim. Sci. Miles City, MT. 56: 264-267.

Philipsson, J., 1982. Genetic aspects of female fertility in dairy cattle. Livest. Prod. Sci. 8: 307-319.

Pienaar, L., Neser, F.W.C., Grobler, J.P., Scholtz, M.M. & MacNeil, M.D., 2015. Pedigree analysis of the Afrikaner cattle breed. Anim. Genet. Resour. 57: 51-6.

Pinedo, P.J. & De Vries, A., 2010. Effect of days to conception in the previous lactation on the risk of death and live culling around calving. J. Dairy Sci. 93: 968-977.

Potocnik, K., Gorjanc, G., Stepec, M. & Krnik, J., 2010. Genetic evaluation for longevity in Slovenian Simmental cattle. Acta Agraria Kopasvariensis. 14: 153-160.

Pryce, J.E., Coff, M.P. & Brotherstone, S., 2000. The genetic relationship between calving interval, body condition score and linear type and management traits in registered Holsteins. J. Dairy Sci. 83: 2664-2671.

Pryce, J.E., Coffey, M.P. & Simm, G., 2001. The relationship between body condition score and reproductive performance. J. Dairy Sci. 84:1508-1515.

Ram, S.B. & Balaine, D.S., 1979. Factors affecting the lactation length and calving interval in Tharparkar cattle. Haryana Agricultural University Journal of Research 9: 107-109.

Ramsay, K., Smuts, M. & Els, H.C., 2000. Adding value to South African landrace breeds: conservation through utilisation. FAO/UNEP Animal Genetic Resources Information Bulletin, 27: 9-16.

Ranberg, I.M.A., Steine, T. & Klemetsdal, G., 1997. Breeding for female fertility - current status and future possibilities in Norway. Interbull Bulletin. 18: 87-90.

Rauw, W.M., Kanis, E., Noordhuizen-Stassen, E.N. & Grommers, F.J., 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. Livest. Prod. Sci. 56: 15-33.

Rege, J.E.O., 1999. The state of African cattle genetic resources I. Classification framework and identification of threatened and extinct breeds. Anim. Genet. Res. Inf. 25: 1-25.

Rendel, J.M. & Robertson, A., 1950. Some aspects of longevity in dairy cows. Emp. J. Exp. Agric. 18: 49-56.

Rennie, T., Light, D., Rutherford, A., Miller, M., Fischer, I., Pratchett, D., Capper, B., Buck, N. & Trail, J., 1976. Beef cattle productivity under traditional and improved management in Botswana. Tropical Animal Health and Production, 9: 1-6.

Rogers, G.W., McDaniel, B.T., Dentine, M.R. & Funk D.A., 1989. Genetic correlations between survival and linear type traits measured in first lactation. J. Dairy Sci. 72: 523-527.

Rogers, G.W., Hargrove, G.L., Cooper, J.B. & Norman, H.D., 1991. Management and genetic influences on survival in Jerseys. J. Dairy Sci. 74: 279-285.

Rogers, P.L., Gaskins, C.T., Johnson, K.A. & MacNeil, M.D., 2004. Evaluating longevity of composite beef females using survival analysis techniques. J. Anim. Sci. 82, 860–866.

Rutherford, M.C. & Westfall, R.H., 1986. Biomes of southern Africa - an objective categorization. Memoirs of the Botanical Survey of South Africa No. 54.

Saeed, A.M., Ward, P.N., Light, D., Durkin, J.W. & Wilson, R.T., 1987. Characterization of Kenana cattle at Um Banein, Sudan. ILCA Research Report 16. International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia.

Sanarana, Y.P., 2015. Genetic characterization of South African Nguni cattle ecotypes using microsatellite markers. MSc Thesis. University of Pretoria, Pretoria, South Africa.

Sanders, J., 2012. Productive longevity of beef cows. Animal Science Dept., Texas A & M University, USA.

Sawa, A. & Bogucki, M., 2010. Effect of some factors on cow longevity. Arch. Teirz. 53(4): 403-414.

Saxton, A.M., Stalder, K.J. & Simpson, R.B., 2014. Angus cow longevity estimates and relationship to production traits.

http://utbfc.utk.edu/Content%20Folders/Beef%20Cattle/Genetics/Publication Accessed in 2 July 2014.

Schoeman, S.J., 1989. Recent research into the production potential of indigenous cattle with specific reference to the Sanga-review. S. Afr. J. Anim. Sci. 19: 55-61.

Scholtz, M.M. & Ramsay, K.A., 2007. Experience in establishing a herd book for local Nguni breed in South Africa. Animal Genetic. Resources Information, 41: 25-28.

Scholtz, M.M., Bester, J., Mamabolo, J.M. & Ramsay, K.A., 2008. Results of the national cattle survey undertaken in South Africa, with emphasis on beef. Appl. Anim. Husb. Rural Dev. 1:1-9.

Scholtz, M.M. & Bester, J., 2010. Off-take and production statistics in the different South African sectors: Results of a structured survey. Appl. Anim. Husb. & Rural Dev. Vol. 3.

Schwab, D. & Hoyer, S., 2013. Beef cow longevity series set for early 2014. Iowa State University, USA.

Sewalem, A., Kistemaker, G.J., Miglior, F. & Van Doormaal, B.J., 2004. Analysis of the relationship between type traits and functional survival in Canadian Holsteins using a Weibull proportional hazard model. J. Dairy Sci. 87: 3938-3946.

Sewalem A., Kistemaker G.J., Ducrocq V., van Doormaal B.J., 2005. Genetic analysis of herd life in Canadian dairy cattle on a lactation basis using a Weibull proportional hazards model. J. Dairy Sci. 88: 368-375.

Sewalem, A., Miglior, F., Kistemaker, G.J., Sullivan, P. & van Doormaal, B.J., 2008. Relationship between reproduction traits and functional longevity in Canadian dairy cattle. J. Dairy Sci. 91: 1660-1668.

Silva, L.N., Gasparino, E., Torres Junior, R.A.A, Euclides Filho, K., Silva, L.O.C., Alencar, M.M., Souza Junior, M.D., Batistelli, J.V.F & Silva, S.C.C., 2015. Repeatability and genotypic correlations of reproductive and productive traits of crossbred beef cattle dams. Genetics and Molecular Research, 14(2): 5310-5319.

Skrzypek, R., 1978. Observation over the milk cows longevity and possibility of her improvment. Prz. Hod. 8:16-8.

Snelling, W.M., Golden, B.L. & Bourdon, R.M., 1995. Within herd genetic analysis of stayability of beef females. J. Anim. Sci. 73: 993-1001.

Solemani-Baghshah, S., Ansari-Mahyari, S., Edris, M. & Nanaei, A.H., 2014. Estimation of Genetic and Phonotypic Trends for Age at First Calving, Calving Interval, Days Open and Number of Insemination to conception for Isfahan Holstein Cows. Int. J. Adv. Biol. Biom. Res. 2(5): 1307-1314.

Solkner, J. & Ducrocq, V., 1999. The survival kit: A tool for analysis of survival data. Interbull Bull. 21: 73-81.

Solkner, J. & Petschina, R., 1999. Relationship between type traits and longevity in Austrian Simmental Cattle. In: Proc of Int Workshop on EU concerned action Genetic improvement of functional traits in Cattle (GIFT) Longevity, May 1999, Jouy-en-Josas, France, Bulltetin 21: 91-5.

Solkner, J., Miesenberger, J., Willam, A., Fuerst, C. & Baumung, R., 2000. Total merit indices in dual purpose cattle. Arch Tierz 43: 597-608.

Strandberg, E. & Roxstrom, A., 2000. Genetic parameters of functional and fertility determined length of productive life in Swedish dairy cattle. Anim. Sci. 70: 383-389.

Strapak, P., Candrak, J. & Aumann, J., 2005. Relationship between longevity and selected production, reproduction and type traits. Czech J. Anim Sci. 50:1-6.

Strapak, P., Juhas, P., Strapakova, E. & Hola, M., 2010. Relation of the length of productive and the body conformation traits in Slovak Simmental breed. Archiv. Tierzucht. 53(4): 393-402, ISSN 0003-9438.

Strapakova, E., Candrak, J., Strapak, P. & Trakovicka, A., 2013. Genetic evaluation of the functional productive life in Slovak Simmental cattle. Archiv. Tierzucht. 56(79): 797-807.

Strapakova, E., Strapak, P. & Candrak, J., 2014. Estimation of breeding values for functional productive life in the Slovak Holstein population. Czech J. Anim. Sci. 59: 54-60.

Szabo, F., Nagy, L., Dakay, I., Marton, D., Torok, M. & Bene, S.Z., 2006. Effects of breed, age of dam, birth year, birth season and sex on weaning weight of beef calves. J. Livest. Sci. 103: 181-185.

Szabo, F. & Dakay, I., 2009. Estimation of some productive and reproductive effects on longevity of beef cows using survival analysis. Livest. Sci. 122: 271-275.

Tanida, H., Hohenboken, W.D. & DeNise, S.K., 1988. Genetic aspects of longevity in Angus and Hereford cows. J. Anim. Sci. 66:640-647.

Teferi, D., 1994, Reproductive and milk yield performance of crossbred dairy cattle at the cooperative farms in the Arsi region, Ethiopia. MSc Thesis. Alemaya University of Agriculture, Dire Dawa, Ethiopia.

Theunissen, A., 2011. The characterization of breed additive and heterosis effects in beef cattle using experimental results. MSc Thesis. University of the Free State, Bloemfontein, South Africa.

Trail, J.C.M, Sones, K., Jibbo, J.M.C, Durkins, J., Light, D.E. & Murry, M., 1985. Productivity of Boran cattle maintained by chemoprophylaxix under trypanosomosis risk. ILCA Research Report 9. International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia.

Uchida, H., 2001. Perspectives of research and project in breeding of Japanese beef cattle. In: Proceedings of the 98th Congress of Japanese Society of Animal Science, 15-16.

Vacek, M., Stipkova, M., Nemcova, E. & Bouska, J., 2006. Relationships between conformation traits and longevity of Holstein cows in the Czech Republic. Czech J. Anim Sci. 51: 327-33.

Van Arendonk, J.A.M., 1986. Economic importance and possibilities for improvement of dairy cow herd life. Proc. of the 6th World Congress Genetics Applied to Livestock Production. Lincoln, USA. 9: 95-100.

Van Arendonk, J.A.M., 1988. Management guides for insemination and replacement decisions. J. Dairy Sci. 71: 1050-1057.

Van der Westhuizen, R.R., Schoeman, S.J., Jordaan, G.F., & van Wyk, J.B., 2001. Heritability estimates derived from threshold analyses for reproduction and stayability traits in a beef cattle herd. S. Afr. J. Anim. Sci. 31: 25-32.

Van Melis, M.H., Oliveira, H.N., Eler, J.P., Ferraz, J.B.S., Casellas, J. & Varona, L., 2010. Additive genetic relationship of longevity with fertility and production traits in Nellore cattle on bivariate models. Gen. Mol. Res. 9(1): 176-187.

Van Raden, P.M. & Klaaskate, E.J.H., 1993. Genetic evaluation of length of productive life including predicted longevity of live cows. J. Dairy Sci. 76: 2758-2764.

Veerkamp, R.F., Brotherstone, S., Engel, B. & Meuwiwissen, T.H.E., 2001. Analysis of censored survival data using random regression models. Anim. Sci. 72: 1-10.

Velarde, L., Carlos, R. & Romero, R. F., 1975. Evaluation of crossbreds on the Atlantic Coast of Costa Rica. I. Reproductive efficiency. Memoria, Asociacion Latinoamericana de Produccion Animal 11: 59.

Vergara, O.D., Elzo, M.A. & Ceron, M.F., 2009. Genetic parameters and genetic trends for age at first calving and calving interval in an Angus-Blanco Orejinegro-Zebu multibreed cattle population in Colombia. Livest. Sci. 126: 318-322.

Vollema, A.R. & Groen, A.F., 1996. Genetic parameters of longevity traits of an upgrading population of dairy cattle. J. Dairy Sci. 79: 2261-2267.

Vollema, A.R. & Groen, A.F., 1997. Genetic correlations between longevity and conformation traits in an upgrading dairy cattle population. J. Dairy Sci. 80: 3006-3014.

Vollema, A., 1998. Selection for longevity in dairy cattle. PhD Thesis. Animal Breeding and Genetics Group, Wageningen Agriculture University. Wageningen, Netherlands.

Vukasinovic, N., Moll, J. & Kunzi, N., 1997. Analysis of productive life in Swiss Brown cattle. J. Dairy Sci. 80: 2572-2579.

Vukasinovic N., Moll, J. & Casanova, L., 2001. Implementation of a routine genetic evaluation for longevity based on survival analysis techniques in dairy cattle populations in Switzerland. J. Dairy Sci. 84: 2073-2080.

Vukasinovic, N., Schleppi, Y. & Kunzi, N., 2002. Using conformation traits to improve reliability of genetic evaluation for herd life based on survival analysis. J. Dairy Sci. 85: 1556-1562.

Wagenaar, K.T., Diallo, A. & Sayers, A.R., 1986. Productivity of transhumant Fulani cattle in the inner Niger Delta of Mali. ILCA Research Report 13. ILCA, Addis Ababa, Ethiopia. 56-57.

Weigel, K.A. & Rekaya, R., 2000. Genetic parameters for reproductive traits of Holstein cattle in California and Minnesota. J. Dairy Sci. 83:1072-1080.

Weigel, K.A., Palmer, R.W. & Caraviello, D.Z., 2003. Investigation of factors affecting voluntary and involuntary culling in expanding herds in Wisconsin using survival analysis. J. Dairy Sci. 86:1482-1486.

Whittier, J.C., 2007. Managing heifers and cow to remain in the herd. PhD Thesis. Colorado State University, USA.

Withycombe, R., Potter, E.L. & Edwards, F.M., 1930. Deferred breeding of beef cows. Oregon Agric. Exp. Sta. Bull. 271: 1-18.

Yague, G., Goyache, F., Becerra, J. & Moreno, C., 2009. Bayesian estimates of genetic parameters for pre-conception traits, gestation length and calving interval in beef cattle. Anim. Reprod. Sci. 114:72-80.

Yazdi, M.H., Visscher, P.M., Ducrocq, V. & Thompson, R., 2002. Heritability, reliability of genetic evaluations and response to selection in proportional hazard models. J. Dairy Sci. 85: 1563-1577.

Zavadilova, L., Nemcova, E., Stikova, M. & Bouska, J., 2009. Relationships between longevity and conformation traits in Czech Fleckvieh cows. Czech J. Anim. Sci. 54 (9): 387-394.

Zavadilova, L. & Stipkova, M., 2012. Genetic correlations between longevity and conformation in the Czech Holstein population. Czech J. Anim. Sci. 57 (3): 125-136.