ESTIMATION OF GENETIC AND PHENOTYPIC PARAMETERS FOR STILLBIRTH IN SOUTH AFRICAN HOLSTEIN CATTLE

by

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BSc AGRICULTURE (ANIMAL PRODUCTION)

A RESEARCH MINI-DISSERTATION

Submitted in fulfilment of the requirements for the degree MASTER OF SCIENCE IN

AGRICULTURE (ANIMAL PRODUCTION)

in the

FACULTY OF SCIENCE AND AGRICULTURE

(School of Agricultural and Environmental Sciences)

at the

UNIVERSITY OF LIMPOPO

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2020

DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo for the degree of Master of Science in Agriculture (Animal Production) has not been submitted by me for a degree at this or any other university, that is my own work in design and in execution, and that all material contained herein has been duly acknowledged.

Signature:………………………………… Date:………………………..

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ACKNOWLEDGEMENTS

Firstly, I acknowledge the Lord God, the father of all creation, the Lord Jesus Christ, and the Holy Spirit for the guidance, strength, health, motivation and for his wisdom and knowledge. It is only through his faithfulness, goodness, unconditional love and grace that this dissertation has become a success.

I would like to express my sincere gratitude to: Prof Banga, Dr Tada and Dr Dube for accepting me as your student and for the unlimited support and patience during the master program. Without their formidable coaching this achievement would not be possible.

This study wouldn’t be a success without the financial support from the National Research Foundation (NRF), University of Limpopo (UL) and the Department of Agriculture Forestry and Fisheries (DAFF) - Professional Development Programme. Thank you to the Integrated Registration and Genetic Information System (INTERGIS) for providing the data which was essential to complete this study. Thanks to the Animal Breeding colleagues for their assistance (such as Abini S, Madilindi M.A, Kekana T.F, Mkhize N.E and Tshilate T.S). Many thanks to all several researchers at the Agricultural Research Council that helped me in all phases of the study and other colleagues and friends from University of Limpopo their support was greatly appreciated. I also express my thanks to Dr O. Matika under the Department of Genetics and Genomics, The Roslin Institute and Royal (Dick) School of Veterinary Studies, University of Edinburgh, for his assistance with software and data analysis.

Thanks to my family who has supported me in so many ways through this journey. Thanks to my brother, Vhutshilo Ratshivhombela for your support. Thanks to my fiancé Livhuwani Tshipuke for your constant support and advice. Finally, I would like to express a million thanks to my sisters, Dakalo Ratshivhombela and Tshifularo Ratshivhombela, without their unconditional support, and love, I would not be here today, I can never thank you more than enough for your support during this wonderful experience.

DEDICATION

This dissertation is dedicated to my late parents and my family for their unconditional love and support and for always being there for me throughout this journey.

ABSTRACT

Stillbirth is a trait of high economic importance in dairy cattle and is increasingly being included in dairy cattle breeding objectives worldwide. In South Africa, however, there is limited information on stillbirth that can be used to improve this trait genetically. Currently, there are no estimated breeding values (EBVs) for any measures of calving performance produced under the national genetic evaluation programme. The current study was, therefore, conducted to assess the incidence of stillbirth and estimate the genetic and environmental influences on maternal effects for stillbirth in South African Holstein cattle, to enable estimation of breeding values for the trait. Data used in the study comprised 13 143 calving records of 7 723 Holstein cows, from 41 herds, participating in the National Dairy Animal Recording and Improvement Scheme during the period 2014 to 2018. Incidence of stillbirth was determined using the PROC FREQ procedure and environmental effects were tested by the General Linear Models (GLM) procedure of Statistical Analysis System (SAS 9.4, 2016). Maternal heritability of stillbirth was estimated by the Restricted Maximum Likelihood (REML) procedure, using the ASReml software (Gilmour *et al*., 2018). The analyses were carried out using a threshold animal model and a repeatability animal model, where the latter considered stillbirth in different parities as repeated measures of the same trait. Environmental effects significantly influencing stillbirth ($p<0.05$) were herd-year-season of calving, dam parity and calf sex, and these were included in the model for variance component estimation. Estimates of maternal heritability effects from the threshold animal model were 0.12±0.04, 0.15±0.08 and 0.14±0.06 for parities 1 to 3, respectively. The repeatability animal model gave a heritability estimate of 0.09±0.03 and a repeatability of 0.18±0.03. The moderate estimates of maternal heritability indicate scope for reducing incidence of stillbirth by selectively breeding cows that are less genetically predisposed to calving dead calves. Stillbirth in different parities should not be considered as the same trait, as indicated by the low repeatability estimate. Results of the current study estimate genetic parameters that are required to compute accurate estimated breeding values (EBVs) for stillbirth, which will enable South African Holstein farmers to select for reduced stillbirths, thus improving calving performance.

Keywords: Stillbirths, Heritability, Repeatability, Estimated breeding values, Genetic evaluation.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Stillbirth is an ethically and economically important trait in dairy cattle, and it is in the interest of both farmers and the public that its incidence is minimised (Banga, 2009). From an animal welfare point of view, it is undesirable that both the dam and calf suffer during calving, and there is also a risk that the dam may be seriously injured (Steinbock *et al*., 2006). Economically, such injury results in costs above those caused by the loss of the calf itself. Stillbirth also causes negative effects such as lower milk production (Berry *et al*., 2007; Bicalho *et al*., 2008). Furthermore, there is increased risk of developing metritis and retained placenta, longer rebreeding intervals, increased risk of involuntary culling, reduced number of calves for sale and fewer replacement heifers (Maizon *et al*., 2004; Bicalho *et al*., 2007; Lombard *et al*., 2007). Thus, high rates of stillbirth in cattle cause large economic losses and are a major concern all over the world. Steinbock *et al*. (2006) pointed out that every ninth calf from Holstein first-calvers is dead at birth or dies within 24 hours after birth. Meyer *et al*. (2001) estimated losses due to stillbirths to be $125.3 million per year in the USA.

Stillbirth can be minimized through accurate selection of animals to achieve genetic improvement, which depends on a sound genetic evaluation programme. Genetic evaluation involves the estimation of individual animals' breeding values (EBVs) for stillbirth in the population. Estimates of genetic parameters for this trait are a prerequisite to the computation of such EBVs. Selection in the South African dairy cattle population has been focussed mainly on increasing milk yield and, to a lesser extent, on improving type (National Dairy Animal Improvement Scheme, 2018). There is limited information regarding functional traits such as stillbirth within the South African dairy cattle population (Banga, 2009). It is important to develop and implement broader breeding objectives, incorporating all economically relevant traits for Holstein cattle in South Africa, including stillbirth. Such an approach will ensure improvement in overall genetic merit. The aim of the current study was to estimate genetic parameters for stillbirth, which will enable South African Holstein farmers to select for reduced stillbirths, thus improving calving performance.

1.2 PROBLEM STATEMENT

The focus in dairy cattle breeding worldwide is gradually shifting from production to functional traits (Miglior *et al*., 2005; Eaglen & Bijma 2009; Eaglen *et al*., 2012). Thus, genetic evaluation of functional traits, such as stillbirth, is essential, for them to be included in selection objectives. Functional traits are those characteristics of an animal which increase profit, not by higher output of products, but by reduced costs of input (Mark, 2004). Examples of these traits are health, fertility, milkability and calving performance (stillbirth and calving ease).

Stillbirth is a major problem in dairy herds worldwide (Harbers, 2000; Meyer *et al*., 2001; Hansen, 2004; Philipsson, 2006; Murray, 2009). An increase in stillbirth rate in cattle has become a major concern all over the world. Increases of 10–13% in rates of stillbirth, in Holstein heifers, have been reported in some countries such USA, Denmark, Sweden and the Netherlands (Harbers, 2000; Meyer *et al*., 2001; Hansen, 2004; Swedish Dairy Association, 2005; Steinbock, 2006). Many countries are including the trait in selection objectives and, variance components are a prerequisite to achieving this. Variance components/genetic parameters are population-and time-(within population) specific; hence, they should always be estimated for each population.

In South African dairy cattle, however, there is paucity of information required to genetically improve stillbirth. There are no estimated breeding values (EBVs) for any measures of calving performance produced under the genetic evaluation programmes in South Africa. This makes it difficult to genetically improve the trait, since EBVs are a prerequisite to genetic improvement through selection. There is, therefore, a need to estimate genetic and phenotypic parameters that are required to compute accurate EBVs for calving traits in South African Holstein cattle.

1.3 RATIONALE

Knowledge of genetic parameters is the basis for sound livestock improvement programmes. Information about the genetic background for traits that are economically relevant in dairy production is needed to improve the genetic evaluation of dairy breeds in South Africa (Banga *et al*., 2002; Miglior *et al*., 2005; Banga, 2009). Estimates of genetic parameters of traits that are desirable to improve in a population are essential for the design and implementation of practical breeding programmes. Reliable estimates of genetic parameters for a specific population are necessary before the trait can be considered for inclusion in the breeding objective. These parameters are a characteristic of the population in which they are estimated and may change over time due to selection and management decisions (Imbayarwo-Chikosi, 2010).

Research on dairy cattle breeding in South Africa has, in the past, mainly focused on increased yields of milk and solids and, to a lesser extent, on improved type (Banga, 2009; Banga, Neser & Garrick, 2014). This underscores the need to include all economically relevant traits in the breeding objective, including calving performance, to achieve higher rates of improvement in overall economic merit.

1.4 Aim

To assess the incidence of stillbirth and estimate the genetic parameters and environmental influences on maternal effects for stillbirth in South African Holstein cattle.

1.5 Objectives

The objectives of this study were to:

I. Assess the incidence of stillbirth in South African Holstein cattle.

II. Determine environmental factors influencing stillbirth in South African Holstein cattle.

III. Estimate maternal heritability and repeatability for stillbirth in the first three parities of South African Holstein cattle.

1.6 Hypotheses

The following null hypotheses were tested:

I. There are no incidences of stillbirth in South African Holstein cattle.

II. There are no environmental factors influencing stillbirth in South African Holstein cattle.

III. There is no maternal additive genetic variation and no permanent environmental effects affecting stillbirth in South African Holstein cattle.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents an overview of the South African dairy industry and background information on the most widely used breed in the country, the Holstein. A review of the importance of stillbirth, including genetic and non-genetic factors influencing the trait is also provided.

2.2 South African dairy industry

Milk production in South Africa contributes about 0,5% to the world's milk production (SA yearbook, 2017/18). The South African dairy industry is comprised of organizations that play different roles and is divided into the primary and secondary sectors. The primary sector represents milk producers, while the secondary sector consists of processors and producers who sell their own produce directly to consumers and retailers (MPO statistics, 2011). Dairy industry matters are coordinated by Milk South Africa, an organization financed by statutory contributions. The Milk Producers' Organization (MPO) negotiates with the government and other establishments on behalf of producers. This organization also makes statistics and management information available to producers, the dairy industry, and other authorities (Kgole, 2013). The Agricultural Research Council (ARC) plays a major role in managing the National Dairy Animal Recording and Improvement Scheme (SA yearbook, 2017/18; MPO statistics, 2011).

According to the SA Yearbook 2017/18, milk producers employ approximately 60 000 farm workers and 40 000 people are indirectly employed by the dairy industry. The gross value of milk produced in 2017 including milk for the producer and on farm consumption was estimated at R 13 890 million, which is 16, 4% higher than the R11 931 million produced in 2013 (DAFF, 2018). Based on these contributions to the South African agricultural sector, the dairy industry is the sixth largest agricultural industry. The main dairy cattle breeds used are Ayrshire, Holstein, Jersey and Guernsey, with the Holstein making up more than 60 per cent (SA Yearbook, 2010/14).

The South African dairy industry comprises various economic activities with significant differences in farming methods and the processing of dairy products, including the production and marketing of raw milk, pasteurised milk and cream, fermented milk, long-life milk and cream, yoghurt, and cheese and its by-products (SA Yearbook 2017/18).

The South African National Genetic Evaluation Programme has, relatively speaking, kept pace with global advances in genetic evaluation methodologies (Banga, 2009). South Africa participates in the interbull evaluation programme, for Ayrshire, Holstein and Jersey breeds, and the traits that are evaluated include production, conformation, longevity, udder health, calving interval and female fertility. Substantial positive phenotypic and genetic trends for yield traits, in the major dairy cattle breeds in South Africa, have been observed over the past 3 decades (Banga, 2009). Considerable genetic change in some linear type traits, particularly in the Holstein breed, has also taken place (Theron and Mostert, 2004). There are, however, serious concerns about a correlated deterioration in functional traits within the population. Previous studies (Banga, 2002; Dube *et al*., 2008; Makgahlela *et al.*, 2008) have pointed to a decline in fitness traits such as longevity, cow fertility and udder health, which may be of high economic value but have not been included in the selection objective.

2.3 The South African Holstein Cattle Breed

The Holstein is the major dairy breed in South Africa. Holstein cattle were bred more than 2000 years ago in the Netherlands. It is believed that the Dutch and German breeders systematically crossed two European breeds (Holstein from North or South America and the Friesian from Europe) for the establishment of the Holstein-Friesian, with the goal of obtaining animals which would make best use of grass. In 1906, the first registration of the breed by the South African Stud Book took place (Gertenbach, 1991). Six years later (1912) the Holstein-Friesland Cattle Breeders Society of South Africa was established (Dairy Herd Improvement in South Africa, 2001; Holstein-Friesland Cattle Breeders Society, 2005).

Figure 2.1: Holstein cattle breed (Lee *et al*., 2016)

2.3.1 Breed characteristics

Holstein cattle can thrive in mild climates. They adapt to all systems of management and utilization, can be stable, but are equally suitable for grazing (Holstein Association USA, 2011). They are not resistant to heat and diseases when in difficult agro-ecological areas (SA Holstein Breeders Society, 2018). Their response to these conditions is a reduced capacity of production. It is a large breed of dairy cattle, with mature live weight ranging from 550 to 650 kg and can calve at 24 and 27 months of age (Gertenbach, 1991). Holstein heifers can be bred at 15 months of age, when they weigh about 362.87 kg (Holstein Association, 2000). It is desirable to have Holstein females calve for the first time between 24 and 27 months of age. Holstein gestation is approximately nine months (Holstein Association, 2000).

The outstanding milk producing ability of Holstein cows has made the breed famous worldwide. It is the leading milk producer of all the dairy breeds and some studies have found it to be the most economical producer of milk fat and milk protein (Dairy moos, 2016; Keller & Allaire, 1990). Holstein cows produce an average of 7 441 kg of milk per 305-day lactation compared to Ayrshire, Guernsey and Jersey which produce 6 072 kg, 5 570 kg and 5 187 kg respectively (NMRIS, 2012). The breed also contributes to meat supply worldwide, has a high growth percentage in the fattening sector and produces meat with a fine fiber (SA Holstein Breeders Society, 2018). High milk production/yield of this breed led the producers and breeders to neglect other traits such as calving performance/stillbirth. It seems that selection for higher milk yields has led to a decline in the calving performance of dairy cows because of the unfavourable genetic correlation between yield and performance (Pryce *et al*., 2004).

2.4 Importance of stillbirth

Selection in the South African Holstein cattle population has, in the past, been focused mainly on increased production and, to a much lesser extent, on type traits (Banga, 2009). It has, however, become imperative to include functional traits in the breeding objective, due to their deterioration and high economic value (Makgahlela *et al*., 2008; Dube *et al*., 2009; Banga, 2014). Functional traits are those characteristics of an animal which increase economic profit, not by higher output of products, but by reduced costs of inputs (Groen *et al*., 1996; Mark, 2004; Lopez de Maturana *et al*., 2007). Such an approach will ensure improvement in overall economic merit.

Stillbirth is an important functional trait in dairy cattle and is defined as a calf born dead or that died within 24 hours after birth with the dam having experienced a normal length gestation (Lombard *et al*., 2007; Gundelach *et al*., 2009; Schuenemann *et al*., 2011). The causes of stillbirth vary from farm to farm and are multi-factorial in nature. Dystocia is one of the biggest risk factors for stillbirth (Meyer *et al*., 2001; Lombard *et al*., 2007; Gundelach *et al*., 2009; Schuenemann *et al*., 2011). The most common lesions found in stillborn calves that suffered a dystocic delivery are rib fractures, subcutaneous edema, subcutaneous hemorrhage, internal and subdural bleeding (Berglund *et al*., 2003). Fetal malformations, such as enlarged thymus, urine bladder defects, heart chamber septum defects and persistence of oval foramen, have been found to be infrequent causes of stillbirth (Berglund *et al*., 2003). Furthermore, abortive agents such as *Leptospira spp* (Smyth *et al*., 1999), *brucellosis*, *Neospora caninum, BVDV* and *IBR* (Berglund *et al*., 2003), could cause weak calves at calving compromising calves' survival within the first hours of life. However, around 35% of the time the cause of death of a newborn, during or within the first 24 hours after birth, cannot be determined (Berglund *et al*., 2003).

2.4.1 Effect of stillbirth on milk production

Stillbirth has been studied to a large extent, partly because of its influence on dairy cow productivity. Several studies have documented reduced production levels in cows that experienced calving difficulties (Philipsson *et al.*, 1979; Meijering, 1984; Dematawewa & Berger, 1997; Johanson & Berger, 2003; Berry *et al.*, 2007; Fouz *et* *al.*, 2013). Difficult calvings may also decrease the amount of fat and protein (kg) produced during lactation in Holstein cattle (Dematawewa & Berger, 1997; Berry *et al.*, 2007; McGuirk *et al.*, 2007). The production level of the dam is also affected by stillbirth (Berry *et al.*, 2007; Bicalho *et al.*, 2008). Bicalho *et al.* (2008) reported a loss of milk due to stillbirths during a 305-day lactation of 323.3 kg (±30.5) in American Holstein cattle. This represented a significant reduction of 1.1 kg per day, compared to cows that did not give birth to a stillborn calf. These losses are comparable to the losses associated with mastitis and lameness. Greater losses of milk were observed in the beginning of lactation and had almost subsided by 270 days in milk (DIM) (Bicalho *et al.*, 2008). Similarly, Berry *et al.* (2007) found that stillbirth resulted in a significant drop in total 60 days milk yield of approximately 51.9 kg.

2.4.2 Economic impact of stillbirth

Stillbirth puts a strain on farm economy by increasing costs in the herd. In the worst case, calving difficulty can also lead to the death of the cow, which can be quite costly (Dematawewa & Berger, 1997; Noakes *et al.*, 2001; Johanson & Berger, 2003; McGuirk *et al.*, 2007). Noakes *et al.* (2001) identified stillbirth and early calf mortality as the most important financial consequences of difficulties at calving. Bicalho *et al.* (2008) estimated the loss of replacement heifers alone to account for $125 million per year in the United States. Mahnani *et al*., (2018) reported that the financial losses associated with stillbirth incidence averaged $938 per case (range from $767 to $1189 in the nine investigated farms) in Iranian Holstein dairy farms.

The decrease in production, fertility and health will also affect cow longevity and increase the risk of culling (Dematawewa & Berger, 1997; Noakes *et al.*, 2001; Johanson & Berger, 2003; McGuirk *et al.*, 2007). This influences the investment cost in the herd, and it creates an earlier need for replacement heifers. Nevertheless, in South Africa, the economic impact of stillbirth for Holstein cattle has not been measured. Knowledge of the consequences of stillbirth and the economic losses associated with it can help the producer when making management decisions.

2.4.3 Effect of stillbirth on animal welfare

High calf loss rates are an international welfare problem, though this is often not recognised (Mee, 2013). Animal welfare has become an important factor in livestock production (Gusstafsson *et al*., 2007; SZÜCS *et al*., 2009). Heifers and cows that go through stillbirths and calving difficulty tend to have impaired health, fertility, and production in the following lactation. Death of the calf or its dam can also occur, and calving difficulty is a leading cause of stillbirths. In certain cases, some of the normal-sized calves being born without complications are also stillborn or die shortly after delivery. There is substantial variation between sire families for both the direct and maternal aspects of stillbirth rate. Obviously, high stillbirth rate is unacceptable from ethical as well as animal welfare and economical points of view. The most stressful part of a cow's life cycle is the calving process and its postnatal aftermath. Thus, stillbirth is not only costly for cattle producers, but it is also a problem for animal welfare and health (Philipson *et al*., 1972; McDermott *et al*., 1992; Szücs *et al*., 2009).

2.4.4 Prevalence of Stillbirth

Meyer *et al*. (2000) reported an overall stillbirth prevalence of 7.1%, and later, the National Animal Health Monitoring System found a prevalence of 8.1% (USDA, 2007c) in U.S. dairy herds. Meyer *et al*. (2001) analyzed 666,341 births and showed that the prevalence of stillbirth ranged from 9.5% to 13.2% in primiparous cows and from 5.3% to 6.6% in multiparous cows in the USA. In Germany, stillbirth prevalence was around 9.7% (Gundelach *et al*., 2009). It is important to note that studies considered a stillborn calf from 24 to 48 hours (Meyer *et al*., 2000; USDA, 2007c; Lombard *et al*., 2007; Schuenemann *et al*., 2011). Generally, primiparous cows had a higher prevalence of stillbirths than multiparous cows. Davis *et al*. (2016) reported prevalence of stillbirth in South Africa to be 30% using beef cattle.

2.5 Environmental factors affecting stillbirth

Knowledge of environmental factors affecting calving performance is an important pre-requisite for the proper use and accurate interpretation of data on these traits. These factors include age of the dam at calving, sex of the calf, parity, herd, year and season of calving (Szücs *et al*., 2009; Al-Samarai, 2012).

2.5.1 Calving year and season

Several studies have found year and season of calving to have a significant effect on stillbirth in dairy cows (Meyer *et al*., 2001; Hansen *et al*., 2004; Al-Samarai, 2012). According to Al-Samarai, (2012), significant effects of calving season on stillbirth may be due to the differences in temperatures, disease incidence and nutrition. Fiedlerova *et al*. (2008) indicated that Holstein cows calving in spring months had more difficult calvings, leading to more stillbirths than those calving in autumn months. In a study on primiparous and multiparaous Iraqi Holstein cows, Al-Samarai (2012) reported that calving season had influence on stillbirth in the first three lactations. The highest incidences of stillbirth were in summer calving cows and lowest in winter calvers. About 14.60% of stillbirths occurred in heifers, 10.71% in multiparous cows, and the overall incidence was 11.36% (Al-Samarai, 2012). These results were supported by several other researchers (Bar-Anan *et al*., 1976; Lindstrom & Villa 1977; Martinez *et al*., 1983; Erf *et al*., 1990; Meyer *et al*., 2001). Contrary to these findings, McClintock (2004) reported higher incidence of stillbirth in winter and autumn months (August) compared to summer, which coincided with the birth of the largest calves, the longest gestation length and the coldest temperatures. Silva del Rio *et al*. (2007) also found higher incidences of stillbirth in Holstein cows to be in the colder months, which corresponds with the seasonal decrease in environmental temperatures in Wisconsin. Fuerst & Egger-Danner (2003) suggested slightly easier calvings in late summer and autumn to be a result of pasturing activity and better condition of heifers/cows. Meyer *et al*. (2001) and Hansen *et al*. (2004) reported that percentage of stillbirths differs significantly by year of calving. The variation may reflect true biological differences across populations over time, or differences among the studied samples.

2.5.2 Parity of the dam

Literature indicates that dam parity influences stillbirth in dairy cattle (Eriksson *et al*., 2003a; Berry *et al*., 2007; Johanson & Berger 2003; Fiedlerova *et al*., 2008). Many studies observed a higher incidence of stillbirth in the first parity compared to later parities (Meijering, 1984; Berger *et al*., 1992; Eriksson *et al*., 2004a; Berry *et al*., 2007). In a study on perinatal mortality in Holstein cattle, Johanson & Berger (2003) observed that first parity cows had a 95% higher risk of stillbirth than cows in later parities. Berger *et al*. (1992) reported a significant effect of parity in both calving difficulty and stillbirth in Angus cattle, with cows having significantly less problems at calving compared to heifers. They noted that cows were 11.9% times more likely to not need any assistance at calving and 2.7% times more likely to have a live born calf compared to heifers. Similar results were obtained for stillbirth in U.S and Swedish Holstein cattle, where stillbirths were 11% in the first calving and 5.7% in the second calving (Martinez *et al*., 1984; Meyer *et al*., 2000). These findings were in line with other research (Hansen *et al*., 2004; Berry *et al*., 2007; Bicalho *et al*., 2007).

The significant effect of parity on stillbirth may be due to the disproportion between calf size and the pelvic area, which causes a difficult calving and increases stillbirth incidence (Meyer *et al*., 2001; Kratochvilova *et al*., 2002; Steinbock *et al*., 2003; Hansen *et al*., 2004; Bicalho *et al*., 2007). According to Nogalski (2003), delivery problems are mainly caused by the difference between the size of the calf and the pelvic dimensions of the dam. Also, the fact that heifers have not achieved their full development and mature body size yet, calf delivery. Delivery progress in the first parity is controlled by more or slightly different factors than in other parities ((Adamec, 2006). They attributed this to heifers being less mature at the common calving age resulting in a lower capacity to support and nourish a growing foetus.

2.5.3 Calving age

Age at calving has a significant effect on stillbirth (Szücs, 2009; Adrian & Barragan, 2015). Holstein heifers less than 24 months old were found to be particularly affected (Mellor, 2004). Ettema and Santos (2004) found that breeding heifers early (less than 15 months of age), before they are sufficiently developed, increases the risk of dystocia. Similarly, Mee (2008) and Bluel (2011) reported that stillbirth increases as the age at first calving decreases. They noted that heifers which calved before 24 months of age are more prone to have stillborn calves than those which calved at 24 months or older. According to Mee *et al*. (2014), the increase in stillbirth observed in younger heifers may be associated with increased risk for dystocia due to small pelvic size. Excellent nutritional management and timing of breeding will avoid economic losses due to increased feed costs and calving-related losses (stillbirth) (Gabler *et al*., 2000).

2.5.4 Herd

Herd has been found to significantly influence stillbirth (Luo *et al*., 2002; Berglund *et al*., 2003; Vallée *et al*., 2013). Bicalho *et al*. (2008) reported large variation in the frequency of stillbirths among herds. They noted that some herds had incidences at 4.1 % while others recorded incidences as high as 14.3 % in Holstein dairy cows in the U.S.A. This variation may partly be attributable to differences in management practices among the herds, as well as environmental conditions (Bicalho et al., 2008; Vallée *et al*., 2013). Furthermore, not all calvings are monitored in the field and the proportion of monitored calving events will differ between herds. How these calving events are recorded compared to their true value and how individual studies choose to handle these recordings may also vary (Everitt *et al*., 1978; Hickey *et al.*, 2009; Vallée *et al.*, 2013). Differences in herd average genetic merit for calving ease will contribute towards this variation (Fuerst & Egger-Danner, 2003; Alam *et al*., 2017).

2.5.5 Sex of calf

Calf sex has been widely reported to influence incidence of stillbirth in animals (Luo *et al*., 2002; Hickey *et al*., 2007; Gullstrand, 2017). Berglund *et al.* (2003) reported that the birth weight of a calf is related to the sex of the calf, with heifer calves being significantly lighter at birth compared to bull calves. Heavier calves are associated with a higher incidence of calving difficulty and therefore stillbirth (Berry *et al*., 2007). In a study on Swedish Holstein cattle, Steinbock *et al*. (2006) observed that male calves had a higher frequency of calving difficulties and stillbirth in both first and later parities. Luo *et al*. (2002) and Hickey *et al*. (2007) also reported the same pattern in Irish and Canadian Holstein cattle, respectively. Berger *et al*. (1992) observed that heifer calves were 1.5 times more likely to survive the first 24h compared to bull calves.

Al-Samarai (2012) reported that female calves had an incidence of stillbirth of 5.51% in first, 5.42% in second and 7.54% in third parities. On the other hand, the corresponding incidences for male calves were 12.48, 15.15 and 12.76%. These results were similar to those obtained by Martinez *et al*. (1984) and Eriksson *et al*. (2004). The effect of calf sex on incidence of stillbirth is especially significant in cows with large body size like Holstein, which is in general due to the calves' large size increasing the probability of dystocia (Lindstrom & Vilva, 1977).

2.6 Genetic parameters

Genetic parameters are important for the accurate estimation of breeding values for traits of economic importance. This is a prerequisite to the achievement of genetic improvement through selection. Estimation of genetic parameters involves the separation of phenotypic variance into components such as (co)variances due to additive genetic effects and permanent environmental effects (Falconer, 2004). Such parameters provide an indication of the potential for direct or correlated response to selection. It is important to estimate genetic parameters for each population, since they are population-specific and not constant over time.

Linear models have been applied for the genetic evaluation of stillbirth in other studies (Meyer *et al*., 2001b, Jamrozik *et al*., 2005, Ghavi Hossein-Zadeh, 2011). A threshold model (Gianola and Foulley 1983) may, however, be a more valid model because it considers the categorical nature of the trait and accounts for more additive variations in total variation of stillbirth.

2.6.1 Heritability

Heritability is a statistic used in the fields of breeding and genetics to estimate the proportion of phenotypic variation of a trait, in a population, that is due to genetic variation (Wray & Visscher, 2008). Heritability reflects all the genetic contributions to a population's phenotypic variance including direct and maternal effects, where individuals are directly affected by their parent's phenotype (Wray & Visscher, 2008). The heritability of a trait is important in selection as it influences selection accuracy and the rate of genetic progress. It is used to express, on a scale of 0 to 1, the amount of the total phenotypic variation in a trait that is due to the (additive) genetic variation in individuals (Gullstrand, 2017; Falconer, 1981).

Calving traits generally exhibit low heritability, partly because it is not easy to determine the true phenotype for all animals in categorical traits (Oldenbroek & van der Waaij, 2015). The direct genetic effects are the effects of genes possessed by the individual, while indirect (maternal) genetic effects are the effects of the dam’s genotype (Hansen *et al*., 2003). Heritabilities for direct effects are in general higher than for maternal effects in animals (Steinbock *et al*. 2003; Eriksson *et al*., 2004; Steinbock *et al*., 2006). Table 2.1. presents some of the direct and maternal heritability and repeatability estimates for stillbirth from the literature.

Table 2.1: Heritability and repeatability estimates for direct effects (h^2_D) and maternal effects (h^2_M) of stillbirth reported in the literature

Parity	**h^2_D**	**h^2_M**	**Reference**	**Model (s)**
1st	0.05	0.04[DH]	Thomasen *et al*. (2008)	Linear regression model
	0.05	0.06[DH]	Hansen *et al*. (2004b)	Bivariate threshold model
	0.03	0.03[CHS]	Eriksson *et al*. (2004)	Linear animal model
	0.04	0.04[H]	Boelling *et al*. (2007)	Multi-trait model
	0.3	0.9[SRB]	Steinbock *et al*. (2005)	Bivariate model
	0.04	0.07[HB]	Wiggans *et al*. (2008)	Multiparity sire-MGS model
	0.03	0.05[HF]	Harbers, Segeren & de Jong, (2000)	Maternal grandsire model
	0.03	0.04[H]	Al-Samarai, (2012)	MIVQUE
	0.02	0.02[SBH]	Fuerst & Egger-Danner, (2003)	Multivariate model
	0.02	0.03[HF]	Eaglen *et al*. (2012)	Sire, animal, univariate and bivariate model
	0.02	0.05	Philipsson, 1996	
2nd and later	0.19	0.06[DH]	Thomasen *et al*. (2008)	Linear regression model
	0.08	0.15[DH]	Hansen *et al*. (2004a)	Threshold model
	0.05	0.005[DH]	Hansen *et al*. (2004b)	Bivariate threshold model
	0.09	0.04[CHS]	Eriksson *et al*. (2004)	Linear animal model
	0.8	0.8[SRB]	Steinbock *et al*. (2005)	Bivariate model
	0.7	0.3[SLB]	Steinbock *et al*. (2006)	Linear animal model
	0.01	0.01[H]	Boelling *et al*. (2007)	Multi-trait model
	0.00	0.01[HB]	Wiggans *et al*. (2008)	Multiparity sire-MGS model
	0.01	0.01[HF]	Harbers, Segeren & de Jong, (2000)	Maternal grandsire model
	0.007	0.02[H]	Al-Samarai, (2012)	MIVQUE
	0.01	0.01[SBH]	Fuerst & Egger-Danner, (2003)	Multivariate model
	0.02	0.02[HF]	Eaglen *et al*. (2012)	Sire, animal, univariate and bivariate models
	0.6	0.5[H]	Ghavi Hossein-Zadeh, (2011)	Linear and threshold animal model
	0.1	0.08[H]	Ghavi Hossein-Zadeh, (2011)	Linear and threshold animal model
All	0.02	0.03[H]	Al-Samarai, (2012)	Repeatability
	0.01	0.004[H]	Hansen, (2005)	Repeatability
	0.01	0.007[SLB]	Steinbock *et al*. (2006)	Repeatability

h^2_D=direct heritability, h^2_M=maternal heritability, MIVQUE=Variance Quadratic Unbiased Estimation, H=Holstein, DH=Danish Holstein, SLB=Swedish Holstein, SRB = Swedish red and white, CHS = Charolais, Hereford and Simmental, HB = Holstein and Brown Swiss, HF = Holstein Friesian, SBH = Simmental, Brown Swiss and Holstein

The heritability of calving traits widely reported in the literature is low (Harbers, Segeren & de Jong, 2000, Eriksson *et al*. 2004a, Hansen *et al*. 2004b, Boelling *et al*. 2007, Al-Samarai, 2012, Eaglen *et al*. 2012) and Wiggans *et al*. 2008). Higher estimates can be achieved by transforming heritabilities to the underlying normal distribution of the traits (Philipsson *et al*., 1979). The variation in heritability estimates can be due to trait definition and the model used. However, Philipsson *et al*. (1979), Mee, (2008) and Mee, (2013) defined stillbirth as death of the calf before, during or within 48 hours after calving, following a gestation period of at least 260 days, irrespective of the cause of death or the circumstances related to calving. Linear models have been applied for the genetic evaluation of stillbirth in other studies (Meyer *et al*., 2001b, Jamrozik *et al*., 2005, Ghavi Hossein-Zadeh, 2011). A threshold model may be a more valid model because it produces higher heritability estimates and considers the categorical nature of stillbirth, which accounts for more additive genetic variation of this trait than linear models (Gianola and Foulley 1983). In South Africa there are no estimated breeding values (EBVs) for any measures of calving performance produced under the national genetic evaluation programmes.

2.6.2 Repeatability

Repeatability can be regarded as the correlation between measurements made on the same animal over time (Lush, 1937). It is founded on repeated measures of a trait on the same individuals (Falconer, 1981). It describes the accuracy with which early records of an animal's performance in a particular trait can predict its lifetime performance (Boake, 1989). Repeatabilities assist in identifying which animals to cull or keep in a herd, rather than which are the most suitable for breeding (Queensland Government, 2016). A high repeatability indicates that repeated measures of the same individual have substantially less variation than measures of different individuals (Kekana, 2017).

Repeatabilities of stillbirth were from 0.01 for direct effect (Hansen, 2005) to 0.007 for maternal effect (Steinbock *et al*., 2006). Moderate repeatabilities were reported by Al-

Samarai, (2012), for direct and maternal effects of stillbirth in Iranian Holstein cattle. The direct repeatability estimates from a bivariate sire maternal grandsire model (Steinbock *et al*., 2006) were comparable to those obtained from linear sire-model analyses (Hansen, 2005).

2.7 Conclusion

Stillbirth is widely regarded as a functional trait that is desirable to improve in dairy cattle populations worldwide. The trait has been made even more important by heightened concerns about animal welfare and increasing incidences of stillborn calves in dairy herds. Thus, inclusion of the trait in the selection objective for South African Holstein cattle is of paramount importance. Environmental factors such as herd, year and season of calving, parity, age of the dam and calf sex may influence stillbirth; hence they should be considered in models for genetic evaluation of the trait. Generally, low to moderate heritability estimates have been reported for stillbirth in the literature, indicating reasonable scope for improvement through selection.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study site

The study was conducted in South Africa, across the country, on Holstein herds under both intensive and extensive management systems, participating in the National Milk Recording Scheme. Climatic conditions in South Africa generally range from Mediterranean in the southwestern corner to temperate in the inner plateau, and subtropical in the northeast. Most of the country has warm, sunny days and cool nights. Rainfall generally occurs during summer (November through March), although in the southwest, around Cape Town, rainfall also occurs in winter (June to August). Temperatures are influenced by variations in elevation, terrain, and ocean currents more than latitude. Temperature and rainfall patterns vary in response to a high-pressure belt movement that circles the globe during the winter between 25º and 30º south latitude and low-pressure systems occurring during the summer. Rainfall varies considerably from west to east. In the northwest, annual rainfall often remains below 200 millimeters. Much of the eastern Highveld, in contrast, receives 500 millimeters to 900 millimeters of rainfall per year; occasionally, rainfall there exceeds 2,000 millimeters. The geographical coordinates of South Africa are as follows: 30.5595° S, 22.9375° E.

3.2 Study animals and management

The data were for Holstein cows calving over a 10-year period (2008-2017) from herds across South Africa. Cows were raised outdoors all year in open lot, floor pens with enough shade structures in each pen and with a feed alley and other farms have free range cows. Either total mixed ration (TMR) or pasture production systems or a combination of these is used, depending on the region (Scholtz *et al*., 2014). Cows in the TMR herds were fed a total mixed ration (51% forage, 49% concentrate) formulated to meet or exceed the nutrient requirements for a lactating Holstein cow weighing 650 kg and producing 40 kg of 3.5% fat-corrected milk (NRC, 2001). Currently between 65 and 75% of milk production is based on pasture (Meissner, personal communication). However, many of these pasture-based systems increasingly incorporate additional feeding such as concentrates or forage crops, such as hay or silage (Muller & Scholtz, 2014). Most cows were milked two times per day, while some were milked three times and were fed following each milking. Lactation number of cows included in the study varied from one to three; with body condition score of cows at calving ranging from 3.0 to 3.75 (scale 1 to 5; Edmondson *et al*., 1989). Heifers and cows were routinely vaccinated against diseases that hamper reproductive functions, such as infectious bovine rhinotracheitis, bovine viral diarrhoea, para-influenza, bovine respiratory syncytial virus, leptospirosis and brucellosis.

3.3 Data

Individual cow performance and pedigree data of South African Holstein cows, from herds participating in the National Dairy Animal Recording and Improvement Scheme, were obtained from the Integrated Registration and Genetic Information System (INTERGIS) of South Africa. The original data set consisted of 1 048 575 calving records of 314 049 cows, from 3 908 herds, recorded between the year 1994 and 2018. The original pedigree file comprised of 2 534 181 animals.

3.3.1 Trait definition

Stillbirth was defined as a calf born dead or that died within a period of 24 hours after birth and the dam experienced a normal length gestation (Lombard *et al*., 2007; Gundelach *et al*., 2009; Schuenemann *et al*., 2011).

3.3.2 Editing

Data editing was carried out using the Statistical Analysis System software (SAS, 2012). Basic edits included removal of records with missing herd identification number, birth date, calving date or lactation number. Further edits were carried out to delete records with missing calf sex or birth status of the calf. Some herds only recorded data on female calves and these were also removed. In addition, calving age within a lactation was restricted to the ranges 20-40, 30-55 and 45-70 months, respectively, for the first, second and third and later parities. Four seasons of calving were defined: summer (December – February), autumn (March - May), winter (June - August) and spring (September - November) (Mostert *et al*., 2006). Herd-year-season (HYS) of calving was defined as the contemporary group. Contemporary groups with less than three animal records, together with those with less than three sires were removed. Data for the years prior to 2014 were mostly unusable, due to incomplete recording of stillbirth, and was therefore removed. The final edited data set consisted of a total of 13 143 calving records of 7 723 Holstein cows from 41 herds, calving during the period 2014 to 2018.

3.3.3 Pedigree file preparation

A pedigree file was built based on animals in the final edited data set and was traced as far back as possible. Animals with unknown birth dates were removed from the pedigree file. Only cows with known sires and dams were retained. The final pedigree file consisted of 22 346 animals, daughters of 2 665 sires and 14 441 dams.

3.4 Statistical analysis

3.4.1 Non-genetic factors affecting stillbirth

Preliminary analysis was carried out to determine incidences of stillbirth using the PROC FREQ procedure. An analysis of variance was then carried out to determine environmental factors affecting stillbirth, for such factors to be accounted for in the models for variance component estimation. The effects tested were herd-year-season of calving, calf sex, age of the dam and parity. The General Linear Models (GLM) procedure of Statistical Analysis System (SAS 9.4, 2016) was used to fit the following model:

$$y = \mu + HYS_i + SEX_j + PARITY_k + e_{ijkl}$$

Where:

y_{ijkl} is an observation on stillbirth (0=alive, 1=dead);

μ is the overall population mean;

HYS_i is the fixed effect of the i^{th} herd-year-season of calving;

SEX_j is the fixed effect of the j^{th} sex of calf;

$PARITY_k$ is the fixed effect of the k^{th} parity;

β is the linear regression coefficient of dam's age at calving;

AGE is the effect of dam's age at calving;

e_{ijklm} is the random error.

3.4.2 Estimation of genetic parameters

Different models were used to estimate (co)variance components for stillbirth, which was analysed as a trait of the dam, defined as the ability of the dam to give birth to a dead or live calf. The data did not have calf ID records; hence, no direct calf effects were included in the study. The analyses were carried out using a threshold animal model, and a repeatability model. The threshold animal model was fitted to estimate genetic parameters for stillbirth in each of the first three parities. On the other hand, the repeatability model was used to estimate stillbirth over different parities, with parities being considered as repeated measures of the same trait. All the analyses for variance component estimation were conducted by the Restricted Maximum Likelihood (REML) procedure, using the ASReml software (Gilmour *et al*., 2002).

The following animal model was fitted:

$$y = Xb + Za + e \qquad (1)$$

Where:

y is the vector of observations for stillbirth (0=alive, 1=dead);

b is the vector of fixed effects (herd-year-season, calf sex and parity);

a is the vector of random additive genetic effects of the cow;

X is the incidence matrix relating observations to fixed effects;

Z is the incidence matrix relating observations to random additive genetic effects;

e is the vector of random residual effects

The (co) variance structures of the model are:

$$\text{Var}\begin{bmatrix} a \\ e \end{bmatrix} = \begin{bmatrix} A\sigma_a^2 & 0 \\ 0 & I\sigma_e^2 \end{bmatrix} \qquad (2)$$

$$\text{Var}\,[y] = [ZAZ'\sigma_a^2 + I\sigma_e^2] \qquad (3)$$

Where: A is the numerator relationship matrix; I is an identity matrix, σ_a^2 is the direct additive genetic variance, σ_e^2 is the residual variance.

It was assumed that covariance between additive genetic effects and residual errors was equal to zero. It was further assumed that the residual errors were independent, identical and normally distributed with variance $I\sigma_e^2$.

The repeatability animal model used for across parity analysis was as follows:

$$y = Xb + Za + Wpe + e \qquad (4)$$

Where:
y is the vector of observations of stillbirth;
X is the incidence matrix relating fixed effects to observations;
b is the vector of fixed effects influencing stillbirth;
Z is the incidence matrix relating random animal additive genetic effects to observations;
a is the vector of random animal additive genetic effects;
W is the incidence matrix relating random permanent environmental effects to observations;
pe is the vector of permanent environmental effects, to account for effects influencing the repeated stillbirth records;
e is the vector of residual effects.

Random animal additive genetic effects (a) were assumed to have the distribution *a*~ *N* (0, $A\sigma_a^2$), where A is the additive genetic relationship matrix and σ_a^2 is the animal additive genetic variance. Residual effects (e) were assumed to be distributed with *N* ~ (0,$I\sigma_e^2$), where I is an identity matrix, σ_e^2 is the residual variance and *COV* (*a, e*) = *0.* Permanent environmental effects were assumed to be distributed with *N* ~ (0,$I\sigma_{pe}^2$), where I is an identity matrix, $\sigma_{pe}^2$is the variance due to permanent environmental effects and *COV (pe,e)= 0, COV* (*a, pe*) = *0.*

The (co)variance structure for random effects was assumed to be as follows:

$$\mathrm{var}\begin{bmatrix} a \\ pe \\ e \end{bmatrix} = \begin{bmatrix} A\sigma_a^2 & 0 & 0 \\ 0 & I\sigma_{pe}^2 & 0 \\ 0 & 0 & I\sigma_e^2 \end{bmatrix} \qquad (5)$$

Heritabilities (h^2) for animal models were estimated as follows:

$$h^2 = \frac{\sigma_a^2}{\sigma_p^2} \qquad (6)$$

Where:

h^2 = heritability estimate;

σ_a^2 = direct additive genetic variance;

σ_p^2 = phenotypic variance.

Repeatabilities for animal models were estimated as follows:

$$r = \frac{\sigma_a^2 + \sigma_{pe}^2}{\sigma_p^2} \qquad (7)$$

Where:

r = repeatability estimate;

σ_{pe}^2 = permanent environmental variance.

CHAPTER 4: RESULTS

4.1 Descriptive statistics and environmental factors influencing incidence of Stillbirth

A total of 13,143 calving records were used for the final analyses and 6.38% of the calves born from these calvings were stillborn.

Table 4. 1: Environmental factors influencing incidence of stillbirth (%)

Variables	Stillbirth (%)
Calf sex	
Male	$8{,}48^{a}$
Female	$4{,}41^{b}$
Season	
Summer	5,94
Autumn	7,16
Winter	5,82
Spring	6,42
Parity	
1	$8{,}72^{a}$
2	$4{,}38^{c}$
3	$5{,}47^{b}$
Year	
2014	$8{,}26^{a}$
2015	$6{,}24^{b}$
2016	$5{,}57^{b}$
2017	$5{,}93^{b}$
2018	$4{,}54^{b}$

%=Percentage, Different letters in the same column indicate significant statistical differences at ($P < 0.05$, Duncan's test)

Calf sex, parity and year had significant effects ($p<0.001$) on stillbirth; however, season had insignificant effects ($p>0.05$).

Results of the analysis of variance to determine environmental factors influencing incidence of stillbirth are shown in Table 4.1. The factors were calf sex, parity, year and season. Age of the dam and herd were not significant.

4.1.1 Stillbirth incidence in South African Holstein cattle

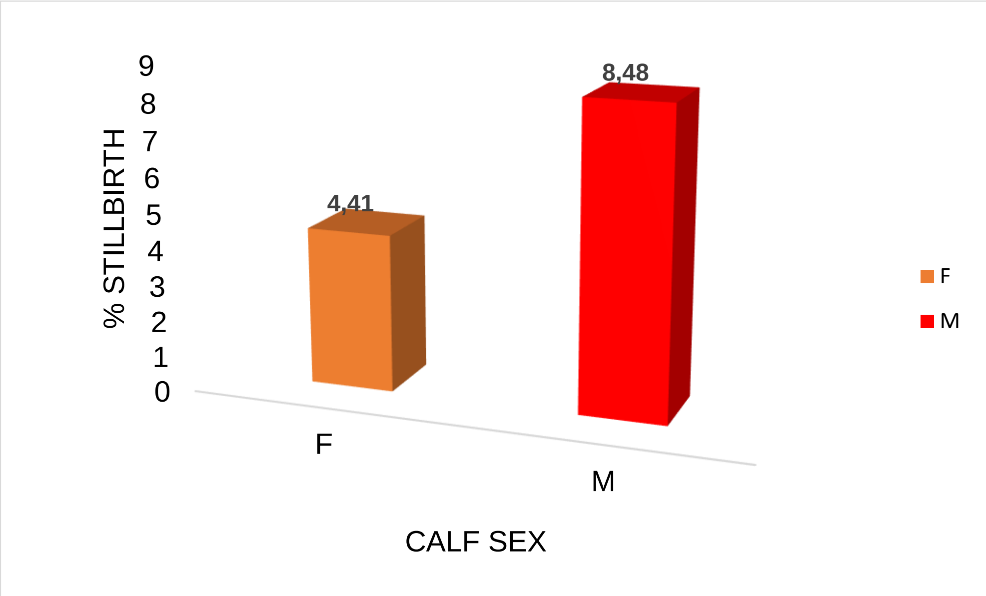

Figure 4.1: Incidence of stillbirth by calf sex in South African Holstein cows.

Male calves had a higher incidence of stillbirth (8,48%) compared to females (4,41%).

Figure 4.1 to 4.3 are graphical presentations of incidences of stillbirth in South African Holstein cattle by sex, season and parity, and Figure 4.4 shows the trend in incidence of stillbirth over the period 2014-2018.

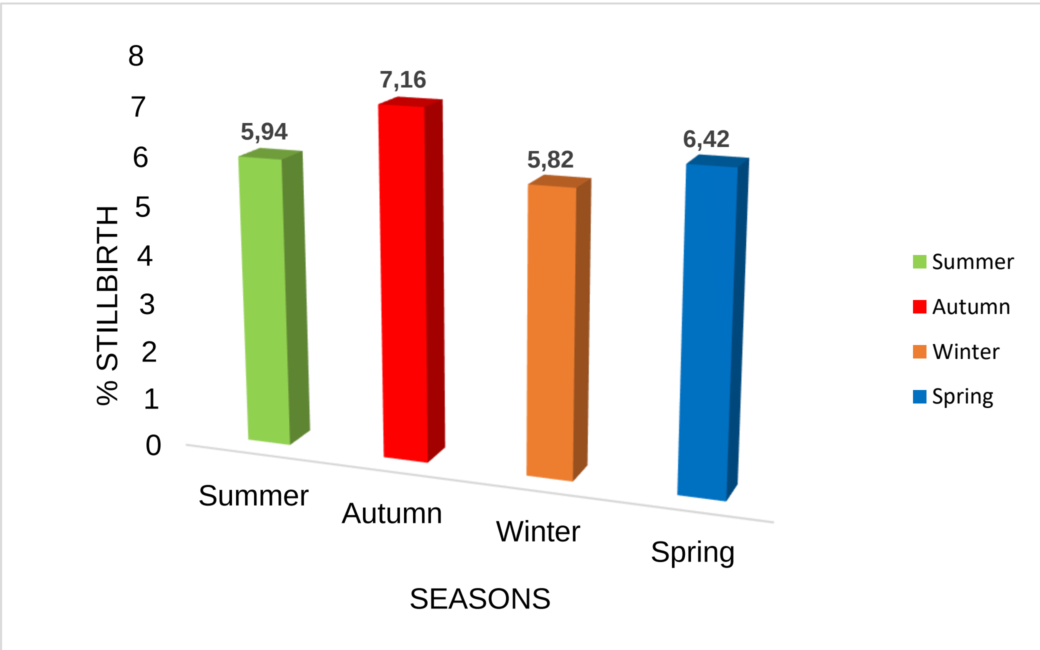

Figure 4.2: Incidence of stillbirth by season in South African Holstein cows.

Cows calving in autumn had the highest incidence of stillbirth (7,16%) and those calving in winter had the lowest (5,82%).

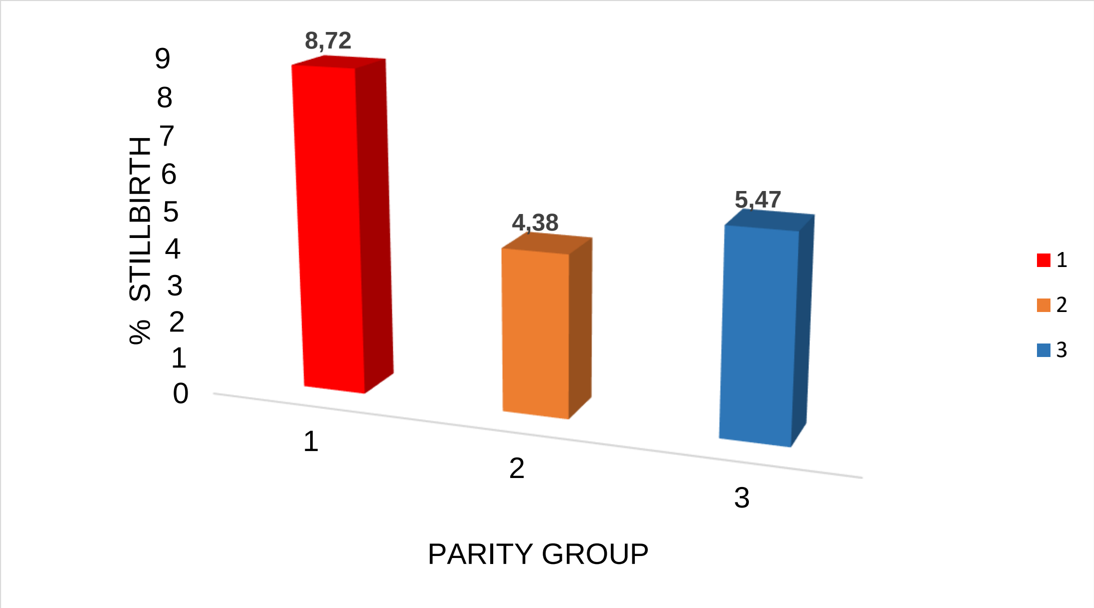

Figure 4.3: Incidence of stillbirth by parity in South African Holstein cows.

First parity cows had the highest incidence of stillbirth (8,72%), followed by third and later parity cows (5,47%), and second parity cows had the lowest incidence (4,38%).

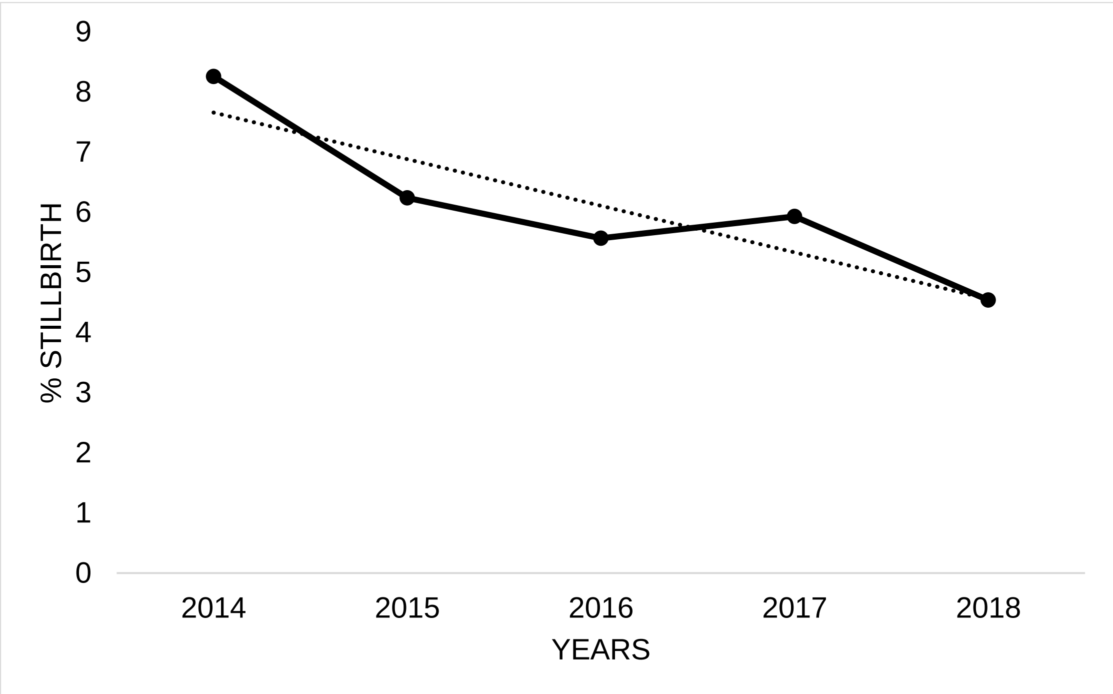

Figure 4.4: Incidence of stillbirth by years in South African Holstein cattle.

Cows which calved in the year 2014 had the highest incidence of stillbirth (8,26%) and 2018 had the lowest incidence of stillbirth (4,54%).

4.2 Heritability and repeatability estimates

Table 4.2 contains the estimates of maternal heritability and repeatability for stillbirth in the first three parities. The heritability estimates for the different parities were generally moderate, ranging from 0.12±0.04 to 0.15±0.08, while the repeatability estimate was moderate (0.18±0.03).

Table 4.2: Heritability (h^2) and repeatability estimates and standard errors (SE) for stillbirth across the first three parities of South African Holstein cows

Parity	Model	h^2± SE	r±SE
1	Threshold animal model	0.12 ± 0.04	
2	Threshold animal model	0.15 ± 0.08	
3	Threshold animal model	0.14 ± 0.06	
All	Repeatability animal model	0.09±0.03	0.18±0.03

h^2=heritability, r=repeatability, SE = standard error

CHAPTER 5: DISCUSSION

5.1 Introduction

The aim of the current study was to assess the incidence of stillbirth and estimate the genetic and environmental influences on maternal effects for stillbirth in South African Holstein cattle. Stillbirth is an important trait, from an economic as well as animal welfare perspective; however, it is not included in the selection objective for South African Holstein cattle (Banga, 2009). Genetic and phenotypic parameters are required for the estimation of breeding values, which will assist in the accurate selection of animals. The main findings of the study are discussed in this chapter. Results obtained are compared to those reported in the literature and their practical application discussed.

5.2 Descriptive statistics

The causes of stillbirth vary from farm to farm and are multi-factorial in nature. The incidence of stillbirth obtained in the current study (6.38%) compares favourably with the values reported by Bicalho *et al*. (2007) in American Holstein dairy cows. The incidence of stillbirth in South African Holstein cattle observed in the current study is slightly lower than those observed elsewhere. This might be due to under-recording of stillbirth by South African farmers.

5.3 Environmental factors influencing stillbirth

Accounting for environmental effects such parity, herd, year and season of calving is important in statistical models for dairy cattle genetic evaluation (Szücs *et al*., 2009; Al-Samarai, 2012). Failure to include these effects will result in inaccurate estimation of breeding values.

5.3.1 Parity

A significant influence of parity on stillbirth has been observed by many researchers (Eriksson *et al*., 2003a; Berry *et al*., 2007; Johanson & Berger 2003; Fiedlerova *et al*., 2008). The higher incidence of stillbirth in the first parity compared to the later parities, as found in the current study, has been reported in several other studies (Eriksson *et* *al*., 2004a; Hansen *et al*., 2004; Berry *et al*., 2007; Bicalho *et al*., 2007; Fiedlerova *et al*., 2008). Bicalho *et al*. (2007), Meyer *et al*. (2001) and Kratochvilova *et al*. (2002) postulated that this may be due to the disproportion between calf size and pelvic area in first calving cows, which causes calving difficult and increases the incidence of stillbirth.

5.3.2 Herd, year and season of calving

Herd-year-season of calving was the contemporary group used in the current study and year had a significant influence on stillbirth. However, in the current study, season and herd were not significant, which was not expected. Significant effects of year of calving on stillbirth in dairy cows have been reported in various other studies (Erf *et al*., 1990; Meyer *et al*., 2001; Luo *et al*., 2002; Berglund *et al*., 2003; Hansen *et al*., 2004; Al-Samarai, 2012; Vallée *et al*., 2013).

Herd had an insignificant effect on stillbirth in the current study. Differences in management practices among herds, as well as environmental conditions are expected to cause variation in the incidence of stillbirth between different herds. However, the reasons why some herds have more stillbirths than others have received little attention in the literature (Mee *et al*., 2013), with few studies being conducted comparing herds with high and low stillbirth rates. An investigation of risk factors for young calf stillbirth between 60 Swedish herds with high and low stillbirth rates found that inadequate calf serum alpha-tocopherol and beta-carotene concentrations, number of faecal pathogens and cases of diarrhoea were significantly more likely in herds with high stillbirth (Torsein *et al*., 2011). A Danish study comparing 28 herds with high and low stillbirth rates found that sociological factors such as the farm manager's belief in whether they could influence loss rates was critical to calf health outcomes leading to more stillbirths (Vaarst & Sorensen, 2009). An Icelandic study of 70 farms found few differences in management practices to be use of AI in heifers, better housing and concentrate feeding between herds with high and low stillbirth rates (Benjaminsson, 2007).

Calving year was one of the most important factors affecting stillbirth. There was a general decline in incidence of stillbirth from 2014 to 2018 in the current study. The influence of year of calving on stillbirth could be attributed to biological variation within the population over time, and/or differences in environmental conditions from year to year. Season of calving has also been found to have a significant effect on stillbirth in dairy cows, in some previous studies (McGuirk, 2004; Al-Samarai, 2012, Bar-Anan *et al*., 1976; Lindstrom & Villa 1977; Martinez *et al*., 1983; Erf *et al*., 1990; Meyer *et al*., 2001). This could mostly be ascribed to seasonal variation in temperature, disease incidence rate, feed availability, and gestation length (Meyer *et al*., 2001; Fiedlerova *et al*., 2008; Al-Samarai, 2012). In pasture herds, differences in pasturing activity are expected to cause variation in the incidence of stillbirths among different seasons.

Fiedlerova *et al*. (2008) reported that Holstein cows calving in spring months had more difficult calvings, leading to more stillbirths than those calving in autumn months in the Czech Republic (Europe). Contrary to these findings, in the current study the Holstein cows calving in autumn had more stillbirths, than those calving in spring, however, the means were not statistically different. Silva del Rio *et al*. (2007) and McGuirk (2004) reported a higher incidence of stillbirth in winter months compared to summer. These differences could be due to variation in different environmental temperatures from different countries, different nutritional supply and variations in diseases the cows might be exposed to in different regions. The seasonal variation in calving traits underlines the importance of including this fixed effect in genetic evaluation models (Steinbock *et al*., 2006).

5.3.3 Calf sex

In concurrence with the current study, Berger *et al*. (1992), Luo *et al*. (2002), Steinbock *et al*. (2006) and Hickey *et al*. (2007) reported male calves to have higher incidence of stillbirth compared to female calves, in previous studies on Irish and Canadian Holstein cattle. Significant calf sex effects on stillbirth have also been observed by several other researchers elsewhere (Martinez *et al*., 1984; Eriksson *et al*., 2004; Al-Samarai, 2012; Gullstrand, 2017). This can be attributed to the fact that male calves are heavier at birth compared to female calves (Berglund *et al.* 2003; Berry *et al*., 2007). According to Lindstrom & Vilva, (1977) the effect of calf sex on incidence of stillbirth is especially significant in cows with large body size like Holstein, thus increasing the probability of dystocia. Thus, calf sex also ought to be accounted for in genetic evaluation models for stillbirth.

5.4 Genetic parameters

5.4.1 Heritability estimates

Heritability measures the strength of the relationship between the phenotype and breeding value of an animal. It is important in the planning of breeding programs, estimation of breeding values of animals, as well as prediction of response to selection. The current study produced heritability estimates that can be used to compute maternal estimated breeding values for stillbirth in South African Holstein cattle. These estimates were generally moderate, ranging from 0.12±0.04 to 0.15±0.08. Similar estimates were reported by Steinbock *et al*. (2006), Ghavi Hossein-Zadeh, (2011), Thomasen *et al*. (2008), Hansen *et al*. (2004a), Hansen *et al*. (2004b), Eriksson *et al*., 2004. Ghavi Hossein-Zadeh, (2011), however, found a slightly higher maternal heritability estimate of 0.5 in second parity, using a threshold animal model, in Iranian Holstein cows. Steinbock *et al*. (2006) also reported higher direct heritability estimates in second parity from a linear animal model analysis of Swedish Red and White dairy cattle. On the other hand, Steinbock *et al*. (2005) obtained a higher maternal heritability estimate of 0.9 in first parity of Swedish Red and White dairy cattle. The accuracy of heritability estimates is depended on the quality of performance records and pedigree information used. Estimates of heritability for a trait can differ among populations and may change over time. These reasons, in addition to the different statistical models used, may explain the disparity of estimates among studies.

The moderate heritability estimates obtained in the current study indicate that significant genetic gain can be achieved if selection is applied on the trait, in the South African Holstein cattle population.

5.4.2 Repeatability estimates

Repeatability measures the extent to which repeated measures of a trait are under the influence of permanent effects. The moderate repeatability estimates obtained in this study indicate average influence of permanent effects on stillbirth in the first three parities of South African Holstein cattle. This indicates that first lactation incidence of stillbirth may predict incidences in later parities in this population. Steinbock *et al*. (2006) found low repeatability estimates of direct and maternal effects in Swedish dairy cattle. Hansen, (2005), also reported very low estimates of 0.004 for maternal effect repeatability of stillbirth, in Danish Holstein cattle.

Chapter 6: CONCLUSIONS AND RECOMMENDATIONS

Stillbirth is currently not included in the breeding objective for South African Holstein cattle. Inclusion of this trait in the breeding program can help to reduce incidence of stillbirths, which may result in an increase in herd profitability and improved animal welfare. The results of the current study provide the basis for implementing this.

The incidence of stillbirth in the SA Holstein cattle population, observed in the current study, is generally lower than those reported elsewhere, which may be due to under-recording by South African farmers. Thus, there is a need to ensure complete recording of incidence of stillbirth in South African Holstein cattle. Herd-year-season of calving, parity and calf sex have a significant effect on stillbirth in South African Holstein cattle. These environmental factors need to be included in statistical models for the genetic analysis of stillbirth in the South African Holstein cattle population. Exclusion of these factors may result in reduced accuracy of prediction of the models, leading to decreased rates of genetic gain.

The moderate estimates of heritability obtained in this study imply that considerable improvement in stillbirth can be achieved through genetic selection. Direct heritability estimates would also be useful to improve the trait. Thus, South African farmers should record all IDs for calves born dead and alive. The moderate repeatability among different parities demonstrates that stillbirth in different lactations cannot be considered as the same trait.

CHAPTER 7: REFERENCES

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