ANALYSIS OF MORTALITY AND CULLING IN FIRST THREE PARITIES OF HOLSTEIN COWS IN THREE REGIONS OF US

by

KAORI TOKUHISA

(Under the Direction of Ignacy Misztal)

ABSTRACT

In order to investigate the seasonal patterns of mortality and culling, and the relationship between 305-days milk yield and those two traits, termination codes from Dairy Herd Improvement (DHI) were used to define mortality and culling, for the analysis. The records from 1999 to 2008 were obtained from US Holstein cows in first three parities in the Southeast, Southwest, and Northeast of United States. Higher mortality and culling rate in summer indicated that heat stress may be one of the possible factors that cause health, reproduction, and production related problems. Low estimated heritability showed the difficulty on improvement in these traits by selection. However, positive correlation between mortality and 305-days milk yield denoted that high milk production could be an indicator of high risk of mortality. Also, negative correlation between culling and milk production indicated preferential veterinary care on high milk producing cows.

INDEX WORDS: culling, mortality, parity, region, season, US Holstein

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B.S., Washington State University, 2009

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2011

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December 2011

DEDICATION

To my family in Japan and my husband.

You were always with me even from a distance.

ACKNOWLEDGEMENTS

I would like to thank Dr. Ignacy Misztal, who has provided great advices, education, and kindness. He has been always busy, but at the same time he has never stopped providing special support to everyone in our lab. It was an honor to be one of his students.

I would like to thank Dr. Rekaya Romdhane and Dr. J. Keith Bertrand for their advices and care. Their advices always gave me courage to go to the next step.

I would like to express a special thank for Dr. Tsuruta Shogo. He has been always willing to help everyone and I was not the exception. He taught me not only animal breeding and genetics and programming, but also personal advices. We also shared the hardship when our family experienced a disaster in Japan. So, I really appreciate his kindness, friendship, patients, and more.

Dr. Albert de Vries, Dr. Marek Lukaszewicz, and Ryan Davis kindly helped me with editing my drafts of papers. They were very patient to this routine works and without their contribution, it was hard for me to complete the writing.

Also, Daniela Lino, Joy King, and Ryan Davis have always given me a good time. They always encouraged me when I faced to hardships. I was very happy to be here because I really liked to be with them.

Finally, I would like to say a special thank you for my husband. Even at his busiest, he always showed his supports, care, understanding, and love. His enormous effort has made my life easier and better.

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CHAPTER 1

INTRODUCTION

The main goal of animal breeding is to maximize genetic potential for production traits and minimize undesirable traits and cost. In the dairy industry, milk yield, fat, and protein percentage are the most economical traits and have been selected for several years. As a result, drastic improvements have been made and Holstein cattle are recognized as the most productive dairy breed in the world. However, heavy selection on production traits and less focus on secondary traits such as health and reproduction traits started to generate problems. Especially, shortening longevity due to early culling and increasing mortality are considered as serious problems, since the problems are very costly from economical and animal welfare points of view. Therefore, improvements on those traits are urgent.

Improvements only for milk production are relatively easy. However, improvements on culling and mortality are difficult since culling and mortality are the results of complex genetic and environmental effects that often interact with each other. Also, some of the vital traits are negatively correlated with milk production making it almost impossible to rapidly improve all traits. Therefore, more knowledge about those traits is necessary. Knowledge of the mechanisms, factors, trends of the problems would tell how to approach problems. The profit from this attempt might be small at the beginning, but improving secondary traits can result in reducing cost and animal welfare issues in the future.

CHAPTER 2

LITERATURE REVIEW

GOALS FOR DAIRY BREEDING AND PRODUCTION

The main goal of dairy breeding is to produce maximum milk yield while maintaining the lowest possible input. To achieve this goal, scientists, breeders, and producers have joined efforts to improve a complex of traits affecting the economic outcome of a dairy enterprise. The traits can be categorized into three components based on the role that each component has in producing profit: production, durability, and reproduction and health. (Miglior, Muir et al. 2005).

Miglior et al. (2005) surveyed selection indices of Holsteins in 2003. In that study, three main components were focused upon. According to their research, the most vital components were production traits, such as milk, fat, and protein yields, and fat and protein percentages, when contribution to the revenue was concerned. In the United States, 54 to 66% of emphasis was put on those production traits (Miglior, Muir et al. 2005). Durability proved to be the second important component. Durability includes traits such as longevity, body size, overall udder, feet and legs, final score, and milking temperament (Miglior, Muir et al. 2005). Durability traits contribute to increased productive life span of cows and increased revenue, and 14 to 32% of emphasis was assigned to the durability traits (Miglior, Muir et al. 2005). Health and reproduction includes udder health, fertility, calving ease, milking speed, etc. (Miglior, Muir et al.

2005). These traits, similarly to durability, influence the costs of production, and 5 to 20% of emphasis was put on health and reproduction.

With enormous effort, milk producers achieved 16% increase in milk yield over the past 10 years from 2001 to 2010 (USDA 2011). However, other economically important, secondary traits that were negatively correlated with milk yield have been depressed due to the selection. As a result, durability, reproduction, and health related traits were negatively affected, which has caused new issues in the dairy industry.

ISSUES ASSOCIATED WITH SELECTION FOR MILK PRODUCTION

Dramatic improvement for milk production generated other issues. Especially, high culling rates and increasing mortality have been recognized as severe problems from economical and animal welfare points of view. Culling and replacing a cow cost about $2,500 (de Vries, 2008) whereas shorten longevity and increasing health and reproductive problems are not acceptable from animal welfare perspectives.

Weigel et al. (2003) reported that high milk producing cows have higher risk of culling. Culling rate in low milk producing cows decreased 1.65 times, and culling rate in high milk producing cows increased 0.18 times in 20 years from 1981 to 2000, in expanding herds. That result indicates voluntary culling in low milk producing cows has declined lower and involuntary culling in high milk producing cows has in creased. And other researchers (Pinedo et al. 2010; R.H Miller et al 2007; Dematawewa and P.J. Berger 1998) also arrived at similar conclusions that there are some relationship between culling or mortality and milk yield. They all stated that improvement of both genetics and management was necessary. However, no effective way to improve the issues has been found yet because of the complex relationships between genetics and environment.

In order to recognize the complex genetic and environmental relationships, reasons for higher culling rate and mortality, possible factors that affect its incidence, together with animals' ability to adapt to a particular environment should be understood.

RISK FACTORS AND REASONS FOR CULLING IN DAIRY COWS

According to some researches (Rogers et al. 1988; Stott 1994), the optimal culling rates were determined at between 19 to 29%. However, actual average culling rates are often higher (G.L. Hadley, 2006). One of the most important ways to reduce culling and mortality is to investigate the risk factors and reasons for culling and mortality. There is an agreement among researches that the main reasons for culling cows are: 1. Poor production 2., Reproduction problems 3., Health related problems.

Culling due to production was reported as 12.8% of total culling reasons in Northeast and upper Midwest from 1993 to 1999 (G.L. Hadley, 2006). At the same time 7.7% of cows were sold for dairy purposes, therefore, 20.5% of culling was due to production related reasons. According to some studies (G.L. Hadley, 2006; J.W. Smith et al. 2000), it appeared that average probability of culling increased with the production level. Hadley (2006) stated that the lowest probability was found at the lowest milk production level (<8182kg: 30.8while the highest probability was found at the high milk production level of 10,910 to 12,272 kg (32.3%) Furthermore, Dematawewa et al. (1998) showed that high milk producing cows had less ability to survive genetically, however, preferential treatment for high milk producing cows made those cows to remain in the herds longer. The above researches show less involuntary culling and more voluntary culling for high milk producing cows. They also indicate that high milk producing cows are exposed to more stress resulting in higher mortality. Therefore, a necessity of improvements on health and reproductive traits especially for high milk producing cows emerges.

Culling rate because of reproduction reaches 18.9% of total culling reasons (G.L. Hadley, 2006). Reproduction problems include; dystocia, retained placenta, cystic ovary, calving interval, pregnancy rate, abortion and etc. Factors that can affect the reproductive performance were parity, reproductive status, calving difficulty score, calf sex and seasons (Delorenzo, Spreen et al. 1992). Pinedo et al. (2010) found that the culling risks for first to sixth parity cows were 29.2, 37.6, 46.4, 53.6, 59.3, and 63.3%, respectively. They also found that the open cows had 2.7 to 6.7 times greater chance of being culled when compared to pregnant cows. However, within pregnant cows, a higher risk of culling is observed in cows with longer days to conception and 280 to 340 days after conception (Pinedo, De Vries et al. 2010). Cows with male offspring have 5 to 7% higher, and twins have 46% higher risk of culling than cows with single female calves. Higher culling rates are result of difficulty of calving associated with males and twins. Also, seasonal pattern brings problems to reproduction. As reported, seasonality in performance can appear due to feed-grain availability, nutrition accessibility, disease susceptibility, and direct extreme weather effect (Smit, McNabb et al. 1996). Therefore, culling due to reproductive reasons shows seasonality under extreme weather conditions. D.E.Ray et al. (1992) reported that high ambient temperature caused depression in calving interval and conception rate in summer.

Culling rate due to health related problems reaches 60.6% of total culling reasons such as injury (26.9%), mastitis (12.1%), feet and leg problems (4.4%), disease (3.0%), and udder problems (3.6%) (G.L. Hadley, 2006). Health problems can be detrimental and leading to death causing large economical loss. Since health problems can be caused by many possible factors, it is hard to improve this trait. In many cases, complex genetic and phenotypic interactions can affect these traits. However, herds exhibit a large effect on culling for health traits. This is mainly due to management, facilities, breeding policies and programs and other culling decisions. Since the associations between genetic and phenotypic effects on health problems are complicated, and exact cause of the problems has yet to be found, further research is needed.

Culling decisions based on production, reproduction, and health-related problems can be affected by several factors that overlap oftentimes. Interactions between the traits, genetic and phenotypic effects affect each other directly and indirectly (Figure 2.1). Since effects may be very complex or interacted, effects can be under estimated or neglected, even though they should not be. If production, reproduction, and health-related problems are not managed successfully, the worst scenario, called “death”, can occur.

MORTALITY IN DAIRY COWS

There are several genetic and environmental complexities that can affect milk yield and mortality of dairy cattle. Since demand for high milk producing cows continues to increase, issues related to U.S. cattle health have become more serious. As production traits are improved upon, an increase in the incidence of death is observed. One factor causing high mortality is thought to be selection and breeding which highly focuses on production with less focus on secondary traits. Holstein cows in the United States show a much higher mortality when compared to other cattle breeds. Average dairy cow mortality was reported as 5.3% while average beef was 1.5% in 2007 (USDA

2007). Although several recent studies have reported an increase in dairy cattle mortality, there is no research available which would address the direct cause of the severe mortality. Determining the direct cause of mortality is difficult since various combinations of factors may affect mortality. Investigation of the direct cause of high mortality is urgent, because mortality is the most ultimate manifestation of health problems and causes both economic and animal welfare issues. If secondary traits are not improved, producers will have to invest more money, time, labor and care in order to keep higher milk production from unsound cows.

In order to improve this situation, breeders, producers, and researchers have started to lower health disorders and mortality incidence without reducing production. The motive behind this is not only animal welfare, but also the extra cost that they have to bear for unhealthy animals. Decline in production is a problem, but cost of a death is also a problem for producers. The cost for a death loss was reported to be $2,665, which included veterinary cost ($50), disposal cost ($35), replacement cost ($2,000), and loss of carcass value ($580) (Miller, Kuhn et al. 2008). From an animal welfare perspective, severe health problems with high production cause animals to suffer.

Since it is beyond of discussion to lower the milk production or slow down the genetic improvement of milk production, environment and management have also been important factors to lower mortality. If environmental effects, such as seasonal and regional effects, are factors that affect mortality, management can lower mortality rate. If problems are successfully managed without lowering production cost, time, and care may decrease and the profit may increase.

SEASONAL AND CLIMATIC EFFECTS ON DAIRY COWS

Seasonal effect is known to have significant influence on performance, and has been well documented. There are four seasonal factors that affect animals' performance; 1. Feed-grain availability 2., Nutrition accessibility 3., Disease susceptibility, and 4., Direct extreme weather effect (Smit, McNabb et al. 1996). Since nutrient availability is dependent on the climate, accessibility to nutrients varies from season to season. For example, C_4 grasses that grow in warm regions are usually low quality when compared with C_3 grasses, which grow in cool regions. Also, feed and grains are not always affordable due to cost or availability in certain seasons.

Alternation of temperature and precipitation regimes may result in spread of disease and parasites into new regions (Baker, Hanson et al. 1993). Direct weather effects such as temperature, humidity, radiation, and precipitation rates are generally the factors that can change climates. There are two types of stress related to the direct weather effect. In cold stress conditions, extra energy is required in order to keep an animal warm. Animals start losing weight if nutrients for maintenance and thermoregulation are unavailable. In order to avoid cold stress, producers must feed additional amount or quality since animals require more energy for thermoregulation. Although this type of stress may lead to serious health issues, cold stress is less severe than heat stress. One reason for the decline in performance in summer has been said to be due to heat stress. By definition, heat stress is a combination of both climatic and non-climatic factors, which lead to either heat gains by body or to a limitation of the dissipation of heat from the cows' body (Leithead and Lind 1964). The first sign of heat stress is elevated body temperature and respiration rate. Body temperature increases because animals reach the point where they cannot dissipate adequate quantity of heat to maintain body thermal balance (Chase 2006). Increased respiration rate causes saliva loss and the lack of buffer in the rumen resulting in increased pH level and causing metabolic alkalosis. Dry matter intake also decreases due to heat stress. These abnormal functions in metabolic, thermal, respiratory, and digestive system cause a depression in reproductive traits; pregnancy rate, fertility, conception rate, duration of estrus, embryonic mortality, and days open all of which directly affect milk yield in dairy cattle (Taylor and Field 2001).

The relationship between temperature and comfort level has been well described. For instance, Figure 2.2 represents the relationship between stress and temperature. At below the low critical temperature, animals experience cold stress and rate of metabolic heat production is increased to maintain homeothermy (Taylor and Field 2001). Above the upper critical temperature, animals are heat stressed and must employ evaporative heat loss mechanism such as sweating and panting to maintain homeothermy. Between lower and upper critical temperature, animals can perform and maintain their health at an optimum condition without regulating their body temperature using additional energy. In dairy cattle, the upper critical temperature is from 25 to 26°C and the lower critical temperature is from -16 to -37°C (Berman, Folman et al. 1985).

Since combinations of temperature and humidity play a role in determining the degree of stress that animals could possibly take. Some scientists have created equations to calculate the degree of discomfort called Temperature Humidity Index (THI). This THI tells how much stress animals may experience under certain temperature and humidity. Depending on the species and environmental condition, these equations for

THI were developed differently. The equation below has been empirically determined in cattle exposed to heat stress conditions in climatic chambers.

$THI = (T_{db} + 0.36 \times T_{dp}) + 41.2$ (Yousef 1985).

Where T_{db} indicates dry bulb point temperature and T_{wb} indicates wet bulb temperature, both in Celsius scale. Huhnke et al. (2001) divided THI into two levels. They categorized THI from 79 to 83, as a dangerous condition for cows, and THI greater than 84, as an emergency condition. The Figure below shows the THI and related cows' condition calculated by the formula.

Production, reproduction, and health performances can be affected by seasonal patterns through metabolic, environmental, and nutritional mechanisms. Since some of the regions in the United States have extreme climates, it is important to know seasonal and climatic effects of the region. These effects may be considered when management decisions are taken in order to improve management. Also, it is important to know if reaction to these effects can be improved genetically to adapt to the environment in the region without lowering milk production.

COWS' PERFORMANCE IN DIFFERENT GEOGRAPHIC REGIONS

According to the Central Intelligence Agency, the total area of United States is stated as 9,826,675km^2, the third largest area in the world. Therefore, the United States is often divided into multiple regions that have distinct geographies, climates, and traditions or practices. Since when breeders select animals, they do not usually pay attention to adaptability of cows in certain regions, some cows may require extra care or equipment to produce comparable amount of milk to cows in other region. The variations in amount of milk in different regions can be due to the difference in management, feeds and feeding, breeding program, selection program, traditional practices, diseases control, etc. However, few studies have been done to compare secondary traits among different regions.

Lengths of days open among different regions were compared by (Oseni, Misztal et al. 2004). This article studies management decisions and relative reproductive ability among different regions. The highest for days open was recorded in the Southeast (155) followed by Midwest (142), Northeast (141), Northwest (140), and Southwest (137).

Observation of reasons for culling in different regions can explain the tendency of problems and management decisions in regions. Some studies show that variations in reasons of culling occur among different regions (Pinedo, De Vries et al. 2010). They found that culling frequencies due to reproductive problems, death, and low production are greater in the South than in the North; whereas North has greater culling frequency due to injury and mastitis (Smith, Ely et al. 2000).

Although those articles show significant differences in productive, reproductive, and health performances between different regions, little information on regional problems can be obtained. It is important to specify how problems arise and how the problems can be improved in the regions. Simultaneous genetic and environmental improvements are necessary since genetic components and management practices differ rom region to region. Therefore, more knowledge about the regional influence on proper management and breeding program is desired.

ANIMAL WELFARE ISSUES

Even though public concern for animal welfare has been growing, animal industries still have animal welfare issues. In the chicken and pig industries, leg conformation problems have been recognized as being at an unacceptable level. Leg conformation problems are a result of selection for fast growth rate. Muscular growth rate has been selected for broiler chickens and pigs; however, bone growth rate is not fast enough to support their large and heavy bodies. This imbalance of growth rates result in overstress on their joints and causes the animals to be unable to walk. In the dairy industry, leg conformation is also a problem as well. Numerous downer cows are usually euthanized even though downed cows are curable. This is because the downer cows are also suspected as BSE (Bovine Spongiform Encephalopathy) infected animals. There are multiple factors that can be an onset of downer cow syndrome. Lameness, mechanical damage to feet, and diseases can lead cows to be downer. Although most of the occurrences are associated with environmental origin (Enevoldsen, Grohn et al. 1991), some are due to genetic factors (Boettcher, Dekkers et al. 1998) that are associated with leg disorders that potentially lead down cow syndrome. For example, lameness has estimated heritability that ranges from 0.10 to 0.22 and that of leg conformation is 0.20 to greater than 0.40 (Boettcher, and Dekkers, 1998; Distl, Koorn et al. 1990; Short and Lawlor 1992; Choi and Mcdaniel 1993).

These problems shown above are due to strict selection toward production traits. And these traits maybe also improved genetically through selection. The traits that breeders select for may be beyond the animals' capacity or may be linked to the traits that are unfavorable. In other words, deleterious traits that should have been removed by natural selection may be remained due to artificial selection for other traits.

In addition to the problems related to breeding and genetics, there are management issues. Transporting dairy cows or calves in a confined truck can cause the cows to become a downer. The mechanical impact on their unstable legs can cause serious damage. Also, there are often too few employees for the number of cows, resulting in less attention and care for the animals. If there are more employees who can observe animals, they may be able to detect disease or injury at an early stage when cows are still curable. Furthermore, facility improvement might be necessary. Hard, and wet concrete can cause lameness.

At a glance, improving animal welfare does not lead to direct profit. Yet, it is important to increase cows' longevity, and lower health disorder and the cost for the treatments. Therefore attempting to heighten the level of animal welfare may bring fewer problems and less cost in the future.

CONCLUSIONS

While dramatic improvement on milk production has occurred, problems with adaptive traits have emerged. Improving milk production is relatively easy. However, some of the vital traits are negatively correlated with milk production making it almost impossible to rapidly improve all traits. Therefore, more knowledge about those traits is necessary. Knowledge of the mechanisms, factors, trends of the problems would tell how to approach problems. The profit from this attempt might be small at the beginning, but improving secondary traits can result in reducing cost and animal welfare issues in the future.

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Figure 2.1 Direct and indirect effects of health disorder on culling (Beaudeau et al. 2000)

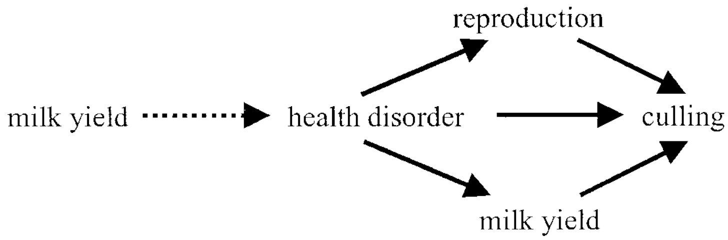

Figure 2.2 Representation of range describing effective ambient temperature and stress (NRC, 1981)

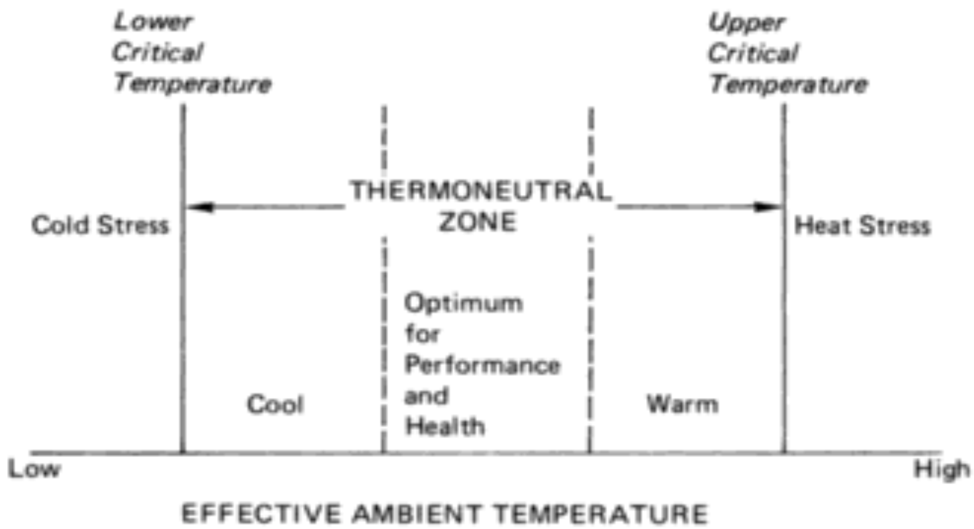

Figure 2.3 Temperature Humidity Index for dairy cattle (Wierama 1990)

NO STRESS — MILD STRESS — MEDIUM STRESS — SEVERE STRESS

DEG	RELATIVE HUMIDITY																				
F	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
75														72	72	73	73	74	74	75	75
80							72	72	73	73	74	74	75	76	76	77	78	78	79	79	80
85			72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
90	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
95	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
100	77	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	
105	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97						
110	81	83	84	86	87	89	90	91	93	94	96	97									
115	84	85	87	88	90	91	93	95	96	87											
120	86	88	89	91	93	94	96	98													

[1]THI = (Dry-Bulb Temp. °C) + (0.36 dew point Temp., °C) + 41.2)

If more than two cows out of 10 have respiratory rates exceeding 100 breaths per minute, then immediate action should be taken to reduce heat stress.

CHAPTER 3

SEASONAL PATTERNS OF MORTALITY AND CULLING RATE OF HOLSTEIN COWS IN FIRST THREE PARITIES IN THREE REGIONS OF US

[1] Tokuhisa,K., S.Tsuruta., and I.Misztal. To be submitted to *Journal of Dairy Science*

ABSTRACT

Several recent research reports have indicated increasing dairy cow mortality in the last 20 years. The reasons for the increase are unclear. This study aimed to investigate seasonal patterns of mortality and culling rate in the first three parities in three regions in the United States. Dairy Herd Improvement (DHI) lactation records were obtained and stratified into three regions: Southeast (SE), Southwest (SW), and Northeast (NE). A total of 3,522,824 records for three parities were used as follows 732,009 (SE), 656,768 (SW), 2,134,047 (NE) from 1999 to 2008. The lactation termination code "death" was used for the mortality risk calculation. In addition to death, lactation termination codes for locomotion problems, poor production, reproductive problems, mastitis or high somatic cell count, udder problems, and other reasons that were not specified, were used for the culling rate calculation. Average annual mortality rates in the first three parities across regions were 3.3%, 4.8%, and 7.2% (SE), 2.4%, 3.3%, and 5.0% (SW), and 2.2%, 3.7%, and 5.4% (NE), respectively. The difference in mortality rates between first and third parities was highest in SE (3.9%) and lowest in SW (2.6%). Average annual culling rate in three parities across three regions were 17.5%, 23.5%, 29.2% (SE), 14.5%, 19.9%, 25.4% (SW), and 14.6%, 23.4%, 31.6% (NE), respectively. The difference in culling rate between first and third parities in the same region was highest in NE (17.0%) and lowest in SW (10.9%). Both mortality and culling rate were higher in summer (July and August) and lower in spring, which may be interpreted that culling in the spring was postponed until summer. In conclusion, mortality and culling rates are influenced by seasonal patterns, geographic regions and parities.

Key words: culling, mortality, parity, regions, seasons, US Holsteins

INTRODUCTION

In the dairy industry, production traits, such as milk, protein, and fat yields have been recognized as the most economical traits, and therefore animals have been selected mainly for these traits (Miglior, Muir et al. 2005). As a result, a 16% increase in milk yield was obtained over the past 10 years (USDA 2011). However, increase mortality and culling rates have been recognized as severe problems accompanying that increase in milk production in dairy industry. According to Miller et al. (2008), the mortality rate increased by 2.48% from 1996 to 2005. While only an annual mortality rate of 1.5% was estimated in the beef industry, an annual rate of 5.7% was reported in the dairy industry in 2007 (USDA, 2010?). Furthermore, the actual annual culling rate is usually higher than the optimal rate, which ranges from 19% to 29 (Bauer et al. 1993; Rogers et al. 1998; Stott 1994). Because high mortality and culling rate are very costly from both economical and animal welfare perspectives, improvements on those traits are important (Weigel et al. 2003).

Currently, indirect selections against mortality and culling rates are provided by selection on productive life (AIPL 2011;Cole et al 2011). Productive life is a part of net merit formula, which is a popular index for ranking dairy bulls.

Culling and mortality are results of complex genetic and environmental factors (De Vries et al. 2010). For instance, As reported by a previous study (Pinedo 2010), patterns of culling and death differ with regions. Regional differences that influence those patterns include different climate, nutrition, prevalence of diseases, management, etc. Many of these differences are confounded. For example, a different management is required for lower culling in hot climates. In the United States, Southeast is known to have a combination of high humidity and temperature, while Southwest has hot climate yet a lot lower humidity, and Northeast has cooler climate, yet high humidity. According to Lacetera et al. (2009), it was proven that high humidity and temperature caused higher mortality due to heat stress.

The highest culling and mortality rates were reported in the hotter parts of U.S. during the summer time (Pinedo et al. 2010). Under heat stress, high producing cow may not be able to dissipate enough heat even with the use of cooling devices. Rising body temperature can lead to health problems, including death (West 2003). Lower producing cow would likely have a better survival but higher production of high producing cows may compensate their lower chances of survival. The exact economics of high production, culling and mortality rates requires knowledge of these rates.

The objective of this research is to describe seasonal trends in mortality and culling of Holstein cows in the first three parities in three U.S. regions using the DHI termination codes.

MATERIALS AND METHODS

Data

DHI data that contained records from 1999 to 2008 were obtained from the USDA. After removing records that had missing observations of lactation termination codes and milk yields, a total of 3,522,824 records of the first three parities in three regions were used. The regions were defined based on their climate characteristics. Southeast (SE) data consisted of 732,009 records and included the following states: North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, and Louisiana. Southwest (SW) data consisted of 656,768 records and included cows in the states of Oklahoma, Texas, New Mexico, and Arizona. Finally, the Northeast (NE) data consisted of 2,134,047 records from Main, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and New York. There were 10 possible termination codes, which indicated the reasons for termination, used for this analysis. Each record could have only one termination code.

Calculations

In order to describe the seasonal pattern of culling and mortality, monthly frequencies were calculated. For the mortality analysis, only the code for death or euthanasia due to the downer cow syndrome was used. For the culling analysis, codes for death, locomotion problems, poor production, reproduction problems, mastitis or high somatic cell count, udder problems, and other reasons or not specified reasons were used. In addition to these seven codes, there were three codes for termination of lactation with or without abortion and for selling cows for dairy purposes. The last 3 codes were regarded and treated neither codes for culling nor mortality. Mortality and culling rates were calculated as followed using SAS (2008):

$$\text{Mortality rate (\%)} = \frac{\text{Number of "dead" animals in each month}}{\text{Total number of animals recorded any possible code}} \times 100$$

$$\text{Culling rate (\%)} = \frac{\text{Number of "culled" animals in each month}}{\text{Total number of animals recorded any possible code}} \times 100$$

RESULTS AND DISCUSSION

Mortality rate

The annual mortality was obtained by summation of the monthly mortality rates. The annual mortality rates were; 3.3%, 4.8%, and 7.2% in SE, 2.4%, 3.3%, and 5.0% in SW, and 2.2%, 3.7%, and 5.4% in NE for first, second, and third parity, respectively. As

Figures 3.1, 3.2, and 3.3 indicate, the months with the highest mortality rates were August and July. The region that had the highest mortality rate was SE. The largest difference of mortality between first and third parities was found in SE (3.9%), and the smallest one in SW (2.7%). By the parity, the differences between the lowest and highest monthly mortalities were 0.13%, 0.21%, and 0.39% in SE, 0.06%, 0.11%, and 0.24% in SW, and 0.02%, 0.07%, and 0.16% in NE for first, second, and third parity, respectively.

Culling rate

The annual culling rates were; 17.5%, 23.5%, and 29.2% in SE, 14.5%, 19.9%, and 25.4% in SW, and 14.5%, 23.4%, and 31.6% in NE for first, second, and third parity, respectively. The culling rate was the highest in late summer. The region that had the highest culling rate for first and second parities was SE (Figures 3.4, 3.5, and 3.6), and the highest culling rate for the third parity was found in NE. The largest difference of culling rates between first and third parities was found in SE (3.9%), and the smallest difference was found in SW (2.7%). Differences between the lowest and highest monthly culling rates were 0.13%, 0.21%, and 0.39% in SE, 0.06%, 0.11%, and 0.24% in SW, and 0.02%, 0.07%, and 0.16% in NE for first, second, and third parities, respectively.

CONCLUSION

Higher mortality and culling rates in summer indicate that cows tend to have health disorders, reproductive problems, milk production problems, or combination of some of them. Mortality rates were higher in SE compared to other two regions and culling rates were higher in NE. The high occurrence of death in SE could be interpreted as due to high temperature and humidity that decline cows performance on production and health conditions because cows are under heat stress. Also, the high occurrence of culling in NE could be explained as due to heavy selection on production that caused heath and reproduction related problems in addition to the heat stress. Because cows in later parities showed more susceptibility towards heat and humidity, culling in early parity may be a good decision. However, because early culling will cause higher replacement cost and animal welfare issues, further analysis that shows the relationship between culling, mortality, and milk production in different parities is necessary for proper culling and breeding decisions.

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Figure 3.1 Mortality rate across month in SE from 1999 to 2008

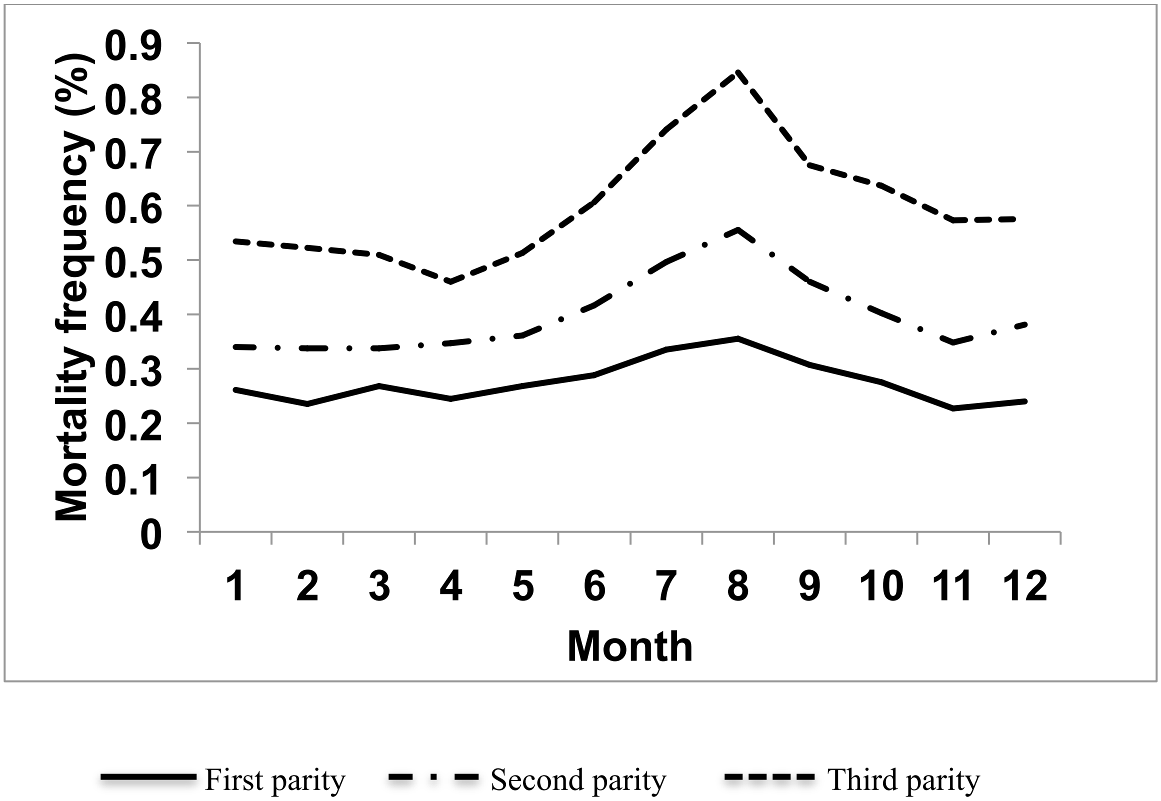


Figure 3.2 Mortality rate across month in SW from 1999 to 2008

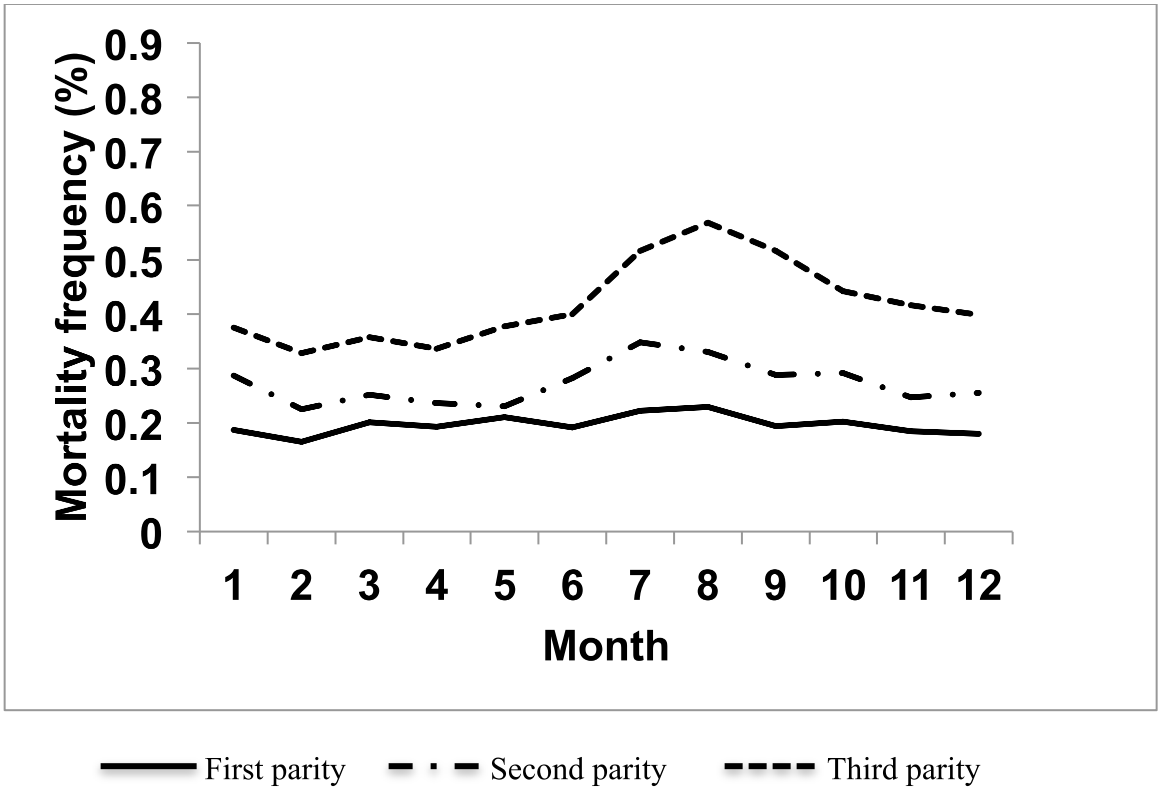


Figure 3.3 Mortality rate across month in NE from 1999 to 2008

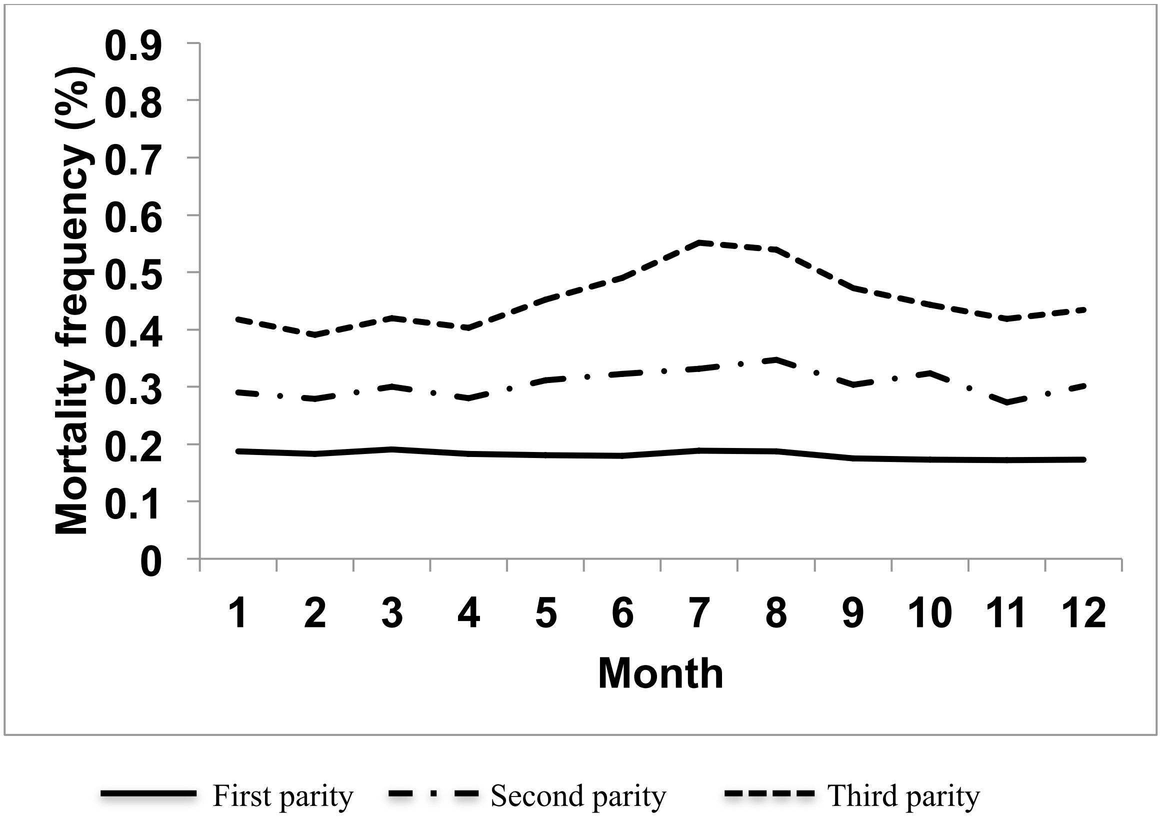


Figure 3.4 Culling rate across month in SE from 1999 to 2008

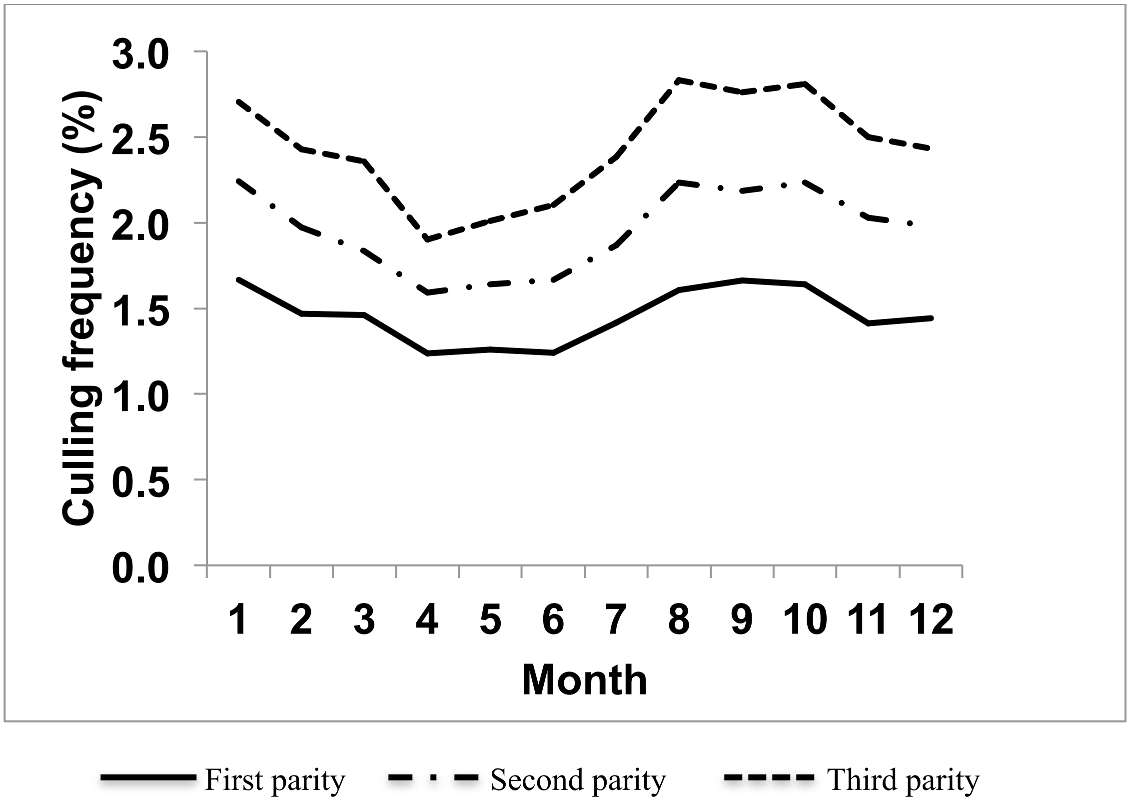


Figure 3.5 Culling rate across month in SW from 1999 to 2008

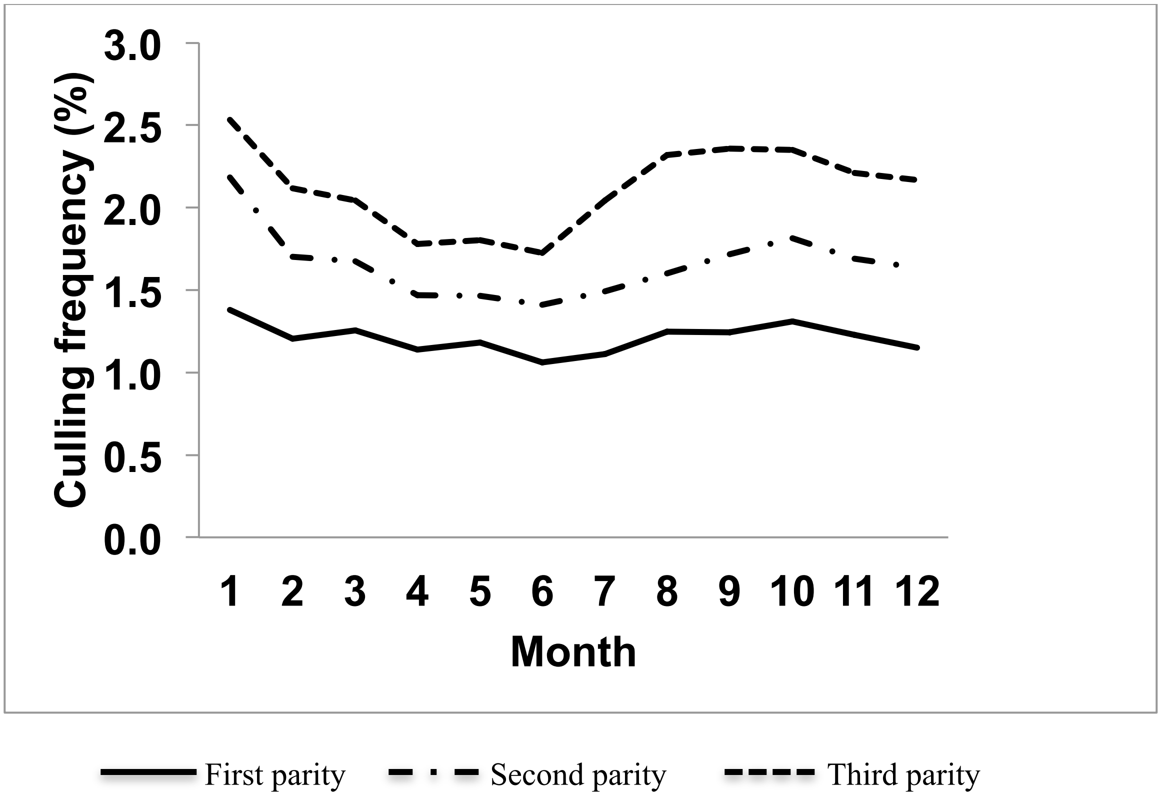
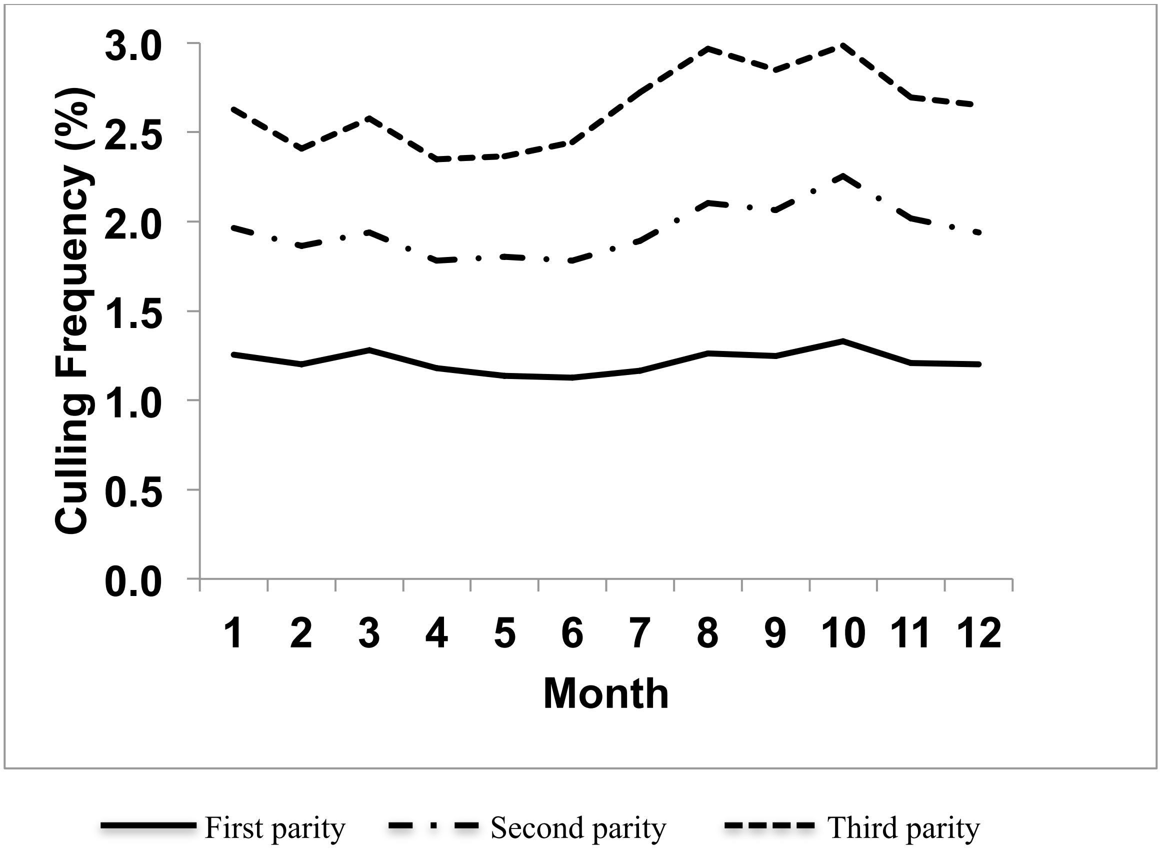


Figure 3.6 Culling rate across month in NE from 1999 to 2008



CHAPTER 4

GENETIC RELATIONSHIPS BETWEEN MORTALITY, CULLING, AND 305-DAYS MILK YIELD OF HOLSTEIN COWS IN THREE REGIONS OF US

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ABSTRACT

Several recent research reports have indicated increasing dairy cow mortality over the years. Although he reasons for the increase are unclear, regional differences may exist. This study aimed to investigate the (genetic) relationship between mortality, culling and 305-d milk yield in three regions of the United States. Dairy herd Improvement (DHI) data from three regions was obtained: Southeast (SE), Southwest (SW), and Northeast (NE). A total of 3,522,824 records for three parities were used: 732,009 (SE), 656,768 (SW), 2,134,047 (NE) from 1999 to 2008. Termination code for "death" was used for mortality analysis, and codes for locomotion problems, poor production, reproductive problems, mastitis or high somatic cell count, udder problems, and other reasons that were not specified, besides death, were used for the culling analysis. A two-trait (305-d milk yield and mortality or culling) animal threshold model fitting the fixed effects of herd-year (for 305-d milk yield), age, DIM, calendar month-of-termination, and random animal genetic effect was employed. Herd-year effect was treated as random for the binary traits mortality and culling in order to avoid extreme category problems. The model was used to estimate variance components, separately for each region and parity. Heritability estimates of mortality were 0.04, 0.05, and 0.04 in SE, 0.06, 0.07, and 0.06 in SW, and 0.06, 0.05, and 0.04 in NE for first, second, and third parities, respectively. Genetic correlations between mortality and 305-d milk yield across first three parities were 0.14, 0.20, and 0.29 in SE, -0.01, 0.01, and 0.31 in SW, and 0.28, 0.33, and 0.19 in NE. Genetic correlations between culling and 305-d milk yield were -0.26, -0.25, and -0.20 in SE, -0.28, -0.31, and -0.23 in SW, and -0.23, -0.20, and -0.17 in NE for first, second, and third parities, respectively. Heritability estimates for culling rate were 0.08,

0.07, 0.06 in SE, 0.07, 0.07, and 0.06 in SW, and 0.07, 0.07, and 0.08 in NE for first, second, and third parities, respectively. Positive correlations between mortality and 305-d milk yield indicate a higher risk of death in high milk producing cows, and negative correlations between culling rate and 305-d milk yield indicate low involuntary culling risk of high milk producing cows.

Key words: culling, mortality, parity, region, season, US Holsteins

INTRODUCTION

In dairy industry, production traits, such as milk, protein, and fat yields have been recognized as the most economical traits and animals have been selected mainly for those traits (Miglior, Muir et al. 2005). As a result, great improvement in milk yield was achieved and 16% increase was estimated over the past 10 years (USDA 2011). However, many studies have reported that the increase in milk yield is accompanied by depression in secondary traits, such as health and reproduction traits (Berger et al. 1981; Lyons et al. 1991; Shanks et al. 1978; Dematawewa et al.1998). Even though improvements in secondary traits do not produce direct revenue, the improvement can lead to a lower involuntary culling rate, and less veterinary costs (Dematawewa and Berger 1998) that lead to higher profits. Also, improvements in secondary traits are recognized to be indispensable from animal welfare perspectives.

Although depression in secondary traits is accompanied with increased milk production, studies have reported that this depression was not directly associated with high milk production (Smith, Ely et al. 2000). Secondary traits can be affected by many other factors, such as season, climate, parity, and management. Furthermore, the main three complexes, production, reproduction, and health interact with each other.

According to Beaudeau et al. (2000), milk yield affects directly health condition and health condition can, in turn, affect reproduction and milk yield, and finally, culling decisions are made based on the performance of reproduction and milk yield. Culling can be categorized as voluntary or involuntary. Voluntary culling is a culling to remove less profitable cows from the herd to replace the cow to high milk producing cows. Involuntary culling is a culling to remove cows with health or reproductive problems. Mortality is considered as involuntary culling and regarded as the most ultimate manifestation of health problems. Phenotypic trends between culling and milk yield has been well documented, however, since culling has multiple reasons and purposes, the true relationships between production and secondary traits is not well understood; however, it is important to know the genetic relationships between milk yield and mortality

The objective of this research is to investigate the genetic relationship between 305-d milk yield and mortality or culling rate in three parities and three US regions.

MATERIALS AND METHODS

Data

DHI data that contained lactation records from 1999 to 2008 was obtained from the USDA. After removing records that had missing observations, a total of 3,522,824 records in first three parities in three regions were used. Southeast (SE) data consisted of 732,009 records and included the following states: North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, and Louisiana. Southwest (SW) data consisted of 656,768 records and included the following states: Oklahoma, Texas, New Mexico, and Arizona. Finally, the Northeast (NE) data consisted of 2,134,047 records from Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and New York. There were 10 termination codes that indicated the reasons for termination of lactation that were recorded. For the mortality analysis, only the code for death or euthanasia due to the downer cow syndrome was used. For the culling reason analysis, codes for death, locomotion problems, poor production, reproduction problems, mastitis or high somatic cell count, udder problems, and other reasons or not specified reasons were exploited. In addition to these 7 codes, there were 3 codes for termination of lactation with and without abortion, and cows sold for dairy purposes were regarded and treated neither codes for culling nor mortality. Death and culling events were treated as categorical traits (1= stay 2=left).

The 305-d mature equivalent milk yields were used to estimate the relationships between milk yield and mortality or culling rate.

Calculations and Models

In order to estimate variance components and heritabilities, the following two-trait animal threshold linear model was used for 305-d milk yield and mortality or culling:

$$y_{ijklm} = HY_i + MOT_j + AGE_k + b(DIM_l) + ANI_m + e_{ijklm}$$

Where

y_{ijklm}= observations of 305-d milk yield and mortality or culling (stay=1 and left=2)

HY_i= fixed effect of herd year for 305-d in milk yield, and random effect for mortality or culling

MOT_j= fixed effect of calendar month of termination

AGE_k= fixed effect of age of a cow

$b(DIM_l)$= fixed regression on days in milk

ANI_m= random animal genetic effect

e_{ijklm}= random error

Covariances for genetic (G), herd-year (HY), and residual (R) effects are calculated as follows:

$$V(G) = \begin{bmatrix} \sigma_{305}^2 & \sigma_{305 \cdot m} \\ \sigma_{m \cdot 305} & \sigma_m^2 \end{bmatrix},$$

$$V(HY) = \begin{bmatrix} 0 & 0 \\ 0 & \sigma_{HY}^2 \end{bmatrix},$$

$$V(R) = \begin{bmatrix} \sigma_{305}^2 & \sigma_{305 \cdot m} \\ \sigma_{m \cdot 305} & \sigma_m^2 \end{bmatrix}$$

where subscript *305* indicates 305-d milk yield, and *m* indicates mortality or culling.

The Gibbs-sampling program THRGIBBS1F90 (Tsuruta 2004), allowing the combination of linear and categorical traits in a single analysis was used to estimate (co)variance components.

The THRGIBBS1F90 program was run separately for each region and parity. The number of Iterations was set to 100,000. The first 10,000 samples were discarded as burn-in, and every 10th sample was kept thereafter. Post-Gibbs analysis by the POSTGIBBSF90 program was conducted to obtain posterior distribution statistics for verification of the parameter estimates.

RESULTS

Variance components and heritability for mortality and 305-d milk yield

Additive genetic variances for mortality were similar for all regions and parities, ranging from 0.05 to 0.08 (Tables 4.1, 4.2, and 4.3). Herd-year variances for mortality were similar for within regions but differed from 0.15 for the first parity in NE to 0.29 for the third parity in SW among regions.

Additive genetic variances for 305-d in milk yield varied from 0.33 kg^2 for the third parity in SE to 0.87 kg^2 for the first parity in NE. The genetic variances decreased as parity increased. The region that has the largest genetic variance of 305-d in milk yield was NE, followed by SW, and SE.

Heritability estimates for mortality were similar for all regions and parities, ranging from 0.04 to 0.07. The region that had the highest heritability for 305-d in milk yield was NE followed by SW and SE. The parity that had the highest heritability was the first parity, and the heritability decreased as parity increased.

Genetic correlations between mortality and 305-d milk yield

Genetic correlations between the two traits were zero or moderately positive, ranging from -0.01 to 0.33 (Tables 4.3, 4.4, and 4.5). Positive relationships indicate that genetically superior cows for milk production tend to have higher risk of death. The residual correlations between mortality and 305-d milk yield were low: 0.06, 0.10, and 0.10 in SE; 0.08, 0.13, and 0.10 in SW, and 0.02, 0.09, and 0.11 in NE for first, second and third parity, respectively. These residual correlations indicate that other effects besides those included in the model may affect mortality of high milk producing cows.

Variance components and heritability for culling and 305-d milk yield

Most of additive genetic variances for culling were not significantly different in all regions and parities, ranging from 0.09 to 0.13 (Tables 4.4, 4.5, and 4.6). Herd-year variances for culling were largest in SW (0.61 in the third parity) and smallest in NE (0.29 in the first parity). Within regions, however, herd-year variances were similar for all parities.

Heritability estimates for culling were similar for all regions and parities, ranging from 0.06 to 0.08.

Genetic Correlations between culling and 305-d milk yield

Genetic correlations between the two traits were negative and low to moderate in magnitude. Negative relationships varied from -0.17 to -0.31 (Tables 4.10, 4.11, and 4.12). These negative relationships indicate that genetically superior cows for milk production face a lower risk of being culled. The negative residual correlations between the two traits, ranging from -0.14 to -0.22, indicate that non-genetic effects may decrease culling rate in high milk producing cows. The main two factors that cause the negative relationships between the two traits were probably

1. The preferential veterinary care for high milk producing cows
2. Less voluntary culling for high milk producing cows.

DISCUSSION

The small additive genetic variances brought small heritabilities for both mortality and culling. Two things can be considered from these results; 1. small variance detection due to improper model. 2. Simply heritability is very low. Therefore, if the first is the case, further analysis may be required with different models for better variance detection.

If the second is the case, then genetic amelioration of mortality may be difficult, and environmental measures should be taken in consideration.

Positive correlations between mortality and milk yield were interpreted as higher risk of death in high milk producing cows, indicating unfavorable relationships. On the other hand, negative correlations between culling and milk yield indicated preferential veterinary care and less voluntary culling for high milk producing cows. This is probably because producers want to keep animals that have high milk production as long as possible.

CONCLUSION

Positive genetic correlations between mortality and 305-d milk yield were found in all regions and parities except first parity in SW indicate that higher milk producing cows tend to have higher risk of death. On the other hand, negative genetic and residual correlations between culling and 305-d milk yield indicate that high milk producing cows are less likely to be culled. Because the low heritability for culling indicates very little advantage on selection, improvement on both management and genetics would be the way to improve culling, as well as mortality. Because high milk producing cows require high maintenance and cost, the balancing between milk yield and health traits should be considered for future breeding.

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Table 4.1 The mean and SD of genetic (G), residual (R), and herd-year (H) variance components and heritability (h^2) for 305-d milk yield and mortality in first three parities in SE

	First parity		Second parity		Third parity	
	Milk $\times(1000kg)^{-2}$	Mortality	Milk $\times(1000kg)^{-2}$	Mortality	Milk $\times(1000kg)^{-2}$	Mortality
G	0.66(0.01)	0.06(0.01)	0.50(0.02)	0.06(0.01)	0.33(0.02)	0.05(0.01)
R	1.70(0.01)	1.00	2.11(0.02)	1.00	2.24(0.02)	1.00
H		0.21(0.01)		0.22(0.01)		0.21(0.01)
h2	0.28(0.01)	0.04(0.01)	0.19(0.01)	0.05(0.01)	0.13(0.01)	0.04(0.01)

Table 4.2 The mean and SD of genetic (G), residual (R), and herd-year (H) variance components and heritability (h^2) for 305-d milk yield and mortality in first three parities in SW

	First parity		Second parity		Third parity	
	Milk $\times(1000kg)^{-2}$	Mortality	Milk $\times(1000kg)^{-2}$	Mortality	Milk $\times(1000kg)^{-2}$	Mortality
G	0.79(0.02)	0.08(0.01)	0.50(0.02)	0.09(0.01)	0.41(0.03)	0.08(0.02)
R	1.71(0.02)	1.00	2.14(0.02)	1.00	2.23(0.03)	1.00
H		0.27(0.02)		0.29(0.02)		0.27(0.02)
h2	0.32(0.01)	0.06(0.01)	0.19(0.01)	0.07(0.01)	0.15(0.01)	0.06(0.02)

Table 4.3 The mean and SD of genetic (G), residual (R), and herd-year (H) variance components and heritability (h^2) for 305-d milk yield and mortality in first three parities in NE

	First parity		Second parity		Third parity	
	Milk $\times(1000kg)^{-2}$	Mortality	Milk $\times(1000kg)^{-2}$	Mortality	Milk $\times(1000kg)^{-2}$	Mortality
G	0.87(0.01)	0.07(0.01)	0.64(0.01)	0.06(0.01)	0.48(0.01)	0.05(0.01)
R	1.60(0.01)	1.00	1.99(0.01)	1.00	2.06(0.01)	1.00
H		0.15(0.01)		0.16(0.01)		0.16(0.01)
h2	0.35(0.01)	0.06(0.01)	0.24(0.01)	0.05(0.01)	0.19(0.01)	0.04(0.01)

Table 4.4 The mean and SD of genetic (G), residual (R), and herd-year (H) variance components and heritability (h^2) for 305-d milk yield and culling in first three parities in SE

	First parity		Second parity		Third parity	
	Milk $\times(1000kg)^{-2}$	Culling	Milk $\times(1000kg)^{-2}$	Culling	Milk $\times(1000kg)^{-2}$	Culling
G	0.66(0.02)	0.12(0.01)	0.49(0.02)	0.10(0.01)	0.33(0.02)	0.09(0.01)
R	1.70(0.01)	1.00	2.12(0.02)	1.00	2.24(0.02)	1.00
H		0.39(0.01)		0.37(0.02)		0.39(0.02)
h2	0.28(0.01)	0.08(0.01)	0.19(0.01)	0.07(0.01)	0.13(0.01)	0.06(0.01)

Table 4.5 The mean and SD of genetic (G), residual (R), and herd-year (H) variance components and heritability (h^2) for 305-d milk yield and culling in first three parities in SW

	First parity		Second parity		Third parity	
	Milk $\times(1000kg)^{-2}$	Culling	Milk $\times(1000kg)^{-2}$	Culling	Milk $\times(1000kg)^{-2}$	Culling
G	0.79(0.02)	0.13(0.01)	0.50(0.02)	0.11(0.01)	0.41(0.03)	0.10(0.02)
R	1.71(0.02)	1.00	2.14(0.03)	1.00	2.23(0.02)	1.00
H		0.60(0.02)		0.57(0.02)		0.61(0.02)
h2	0.32(0.01)	0.07(0.01)	0.19(0.01)	0.07(0.01)	0.15(0.01)	0.06(0.01)

Table 4.6 The mean and SD of genetic (G), residual (R), and herd-year (H) variance components and heritability (h^2) for 305-d milk yield and culling in first three parities in NE

	First parity		Second parity		Third parity	
	Milk $\times(1000kg)^{-2}$	Culling	Milk $\times(1000kg)^{-2}$	Culling	Milk $\times(1000kg)^{-2}$	Culling
G	0.87(0.01)	0.10(0.01)	0.63(0.01)	0.11(0.01)	0.47(0.01)	0.11(0.01)
R	1.60(0.01)	1.00	1.99(0.01)	1.00	2.06(0.01)	1.00
H		0.29(0.01)		0.31(0.01)		0.32(0.01)
h2	0.35(0.01)	0.07(0.01)	0.24(0.01)	0.08(0.01)	0.19(0.01)	0.08(0.01)

Table 4.7 The mean and SD of genetic (G) and residual (R) correlations between 305-d milk yield and mortality in first three parities in SE

	First parity	Second parity	Third parity
G	0.14(0.07)	0.20(0.06)	0.29(0.08)
R	0.06(0.01)	0.10(0.01)	0.10(0.01)

Table 4.8 The mean and SD of genetic (G) and residual (R) correlations between 305-d milk yield and mortality in first three parities in SW

	First parity	Second parity	Third parity
G	-0.01(0.08)	0.01(0.08)	0.31(0.06)
R	0.08(0.01)	0.13(0.01)	0.10(0.01)

Table 4.9 The mean and SD of genetic (G) and residual (R) correlations between 305-d milk yield and mortality in first three parities in NE

	First parity	Second parity	Third parity
G	0.28(0.04)	0.33(0.04)	0.19(0.05)
R	0.02(0.01)	0.09(0.00)	0.11(0.01)

Table 4.10 The mean and SD of genetic (G) and residual (R) correlations between 305-d milk yield and culling in first three parities in SE

	First parity	Second parity	Third parity
G	-0.26(0.04)	-0.25(0.04)	-0.20(0.06)
R	-0.19(0.01)	-0.15(0.01)	-0.14(0.01)

Table 4.11 The mean and SD of genetic (G) and residual (R) correlations between 305-d milk yield and culling in first three parities in SW

	First parity	Second parity	Third parity
G	-0.28(0.01)	-0.31(0.01)	-0.23(0.01)
R	-0.20(0.01)	-0.15(0.01)	-0.15(0.01)

Table 4.12 The mean and SD of genetic (G) and residual (R) correlations between 305-d milk yield and culling in first three parities in NE

	First parity	Second parity	Third parity
G	-0.23(0.03)	-0.20(0.02)	-0.17(0.03)
R	-0.22(0.01)	-0.17(0.00)	-0.17(0.01)

CHAPTER 5

CONCLUSIONS

The two series of this study on seasonal patterns of mortality and culling frequencies and relationship between milk yield, mortality, and culling of Holstein cows in three parities in three regions of United States aimed to obtain genetic and phenotypic trends of three traits of culling, mortality, and milk yield.

Results of seasonal patterns of culling and mortality indicated higher mortality and culling frequency in summer. The higher frequency can be interpreted as a result of heat stress due to high temperature and humidity in summer. Also, cows in higher parities expressed more susceptibility towards seasonal changes with higher frequencies. Therefore, the results of this study may suggest early culling before cows start to show health, reproduction, and production problems. However, early culling is costly in economic and animal welfare perspectives. Therefore, the second study was designed to obtain the relationships between culling mortality, and culling to see the genetic relationships

Variance components, heritabilities, and correlations were estimated and compared among three parities and three regions. Since small genetic variances and low heritabilities were estimated, it is hard to improve mortality and culling rapidly by selection. However, correlations between mortality and milk yield described the possibility that higher risk of death on higher milk producing cows. While negative relationship between culling and milk yield described low risk of culling for higher milk producing cows, possibly due to preferential veterinary care.

Despite the positive correlations between mortality and milk yield, it is not profitable to slow down the genetic improvement on milk production. Therefore, attempt to improve mortality genetically and phenotypically by selection and an improved breeding program would be the best solution. The results that were obtained from this series of studies can be taken account for future breeding program and culling decisions. However, since global warming has been increasing rapidly, more study to determine the way to increase adaptability and decrease health disorders that are induced by heat and humidity.