Comparisons of Holstein, Brown Swiss, and Jersey cows for age at first calving, first calving interval, and true herd-life up to five years in seven regions of the United States

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ABSTRACT

The objectives of this research were to evaluate breed differences for heat-stress resistance using age at first calving and first calving interval, and to assess breed by region interactions for seven regions of the United States for survival-related traits up to five years of age in Brown Swiss, Holstein, and Jersey cows. Age at first calving and first calving interval were studied in farms with two breeds, with Holstein and Brown Swiss or Holstein and Jersey cows. The survival-related traits were analyzed in farms with one or two breeds. Seven regions within the United States were defined: Northeast, Northwest, Central north, Central, Central south, Southwest and Southeast. The fertility traits were also analyzed in seven individual states: Wisconsin, Ohio, Oregon, California, Arizona, Florida, and Texas. Brown Swiss were older than Holsteins at first calving (833 ± 2.4 d vs. 806 ± 2.0 d in regions, and 830 ± 3.1 d vs. 803 ± 2.4 d in states), but Holsteins and Brown Swiss did not differ for first calving interval. Jerseys were younger than Holsteins at first calving and had shorter first calving intervals ($P < 0.01$). In data from individual states, Holsteins housed with Brown Swiss were older at first calving than Holsteins housed with Jerseys (800 ± 2.7 d vs. 780 ± 2.5 d). Holsteins housed with Jerseys had slightly shorter first calving intervals than Holsteins housed with Brown Swiss, and the interaction of "type of Holstein" with season of the first calving was highly significant ($P < 0.01$). Region and season effects were smaller for Jerseys than for Holsteins, thus, Jerseys showed evidence of heat-stress resistance with respect to

Holsteins. Management modified age at first calving in Holsteins, depending on the type of herd they were located in. Longer calving intervals might have been partly due to voluntary waiting period to breed the cows. The survival-related traits were evaluated up to five years of age. They consisted of stayability, number of completed lactations, days lived, herd-life, and total days in milk. For herds with one breed, the order for stayability to five years of age, from longer to shorter-lived breed was: Brown Swiss, Jersey and Holstein, but for the ratio of days in milk to herd-life the order was: Holstein, Jersey and Brown Swiss, and for the ratio of days in milk to days lived, it was: Jersey, and Holstein and Brown Swiss tied. This last ordering was the same for number of lactations completed by five years of age. The results for two-breed herds were similar since Brown Swiss and Jerseys had larger (Chi-square $P < 0.01$) probabilities of living past five years of age than Holsteins, and for days in milk and number of lactations completed, Jerseys had higher values than Holsteins ($P < 0.01$), but Holsteins and Brown Swiss tied in some analyses. Breed by region interaction was always significant. If all other conditions were assumed equal, Jerseys would give fastest returns by five years of age. The overall conclusion is that Jerseys performed better for the traits analyzed, all of them highly influenced by environmental conditions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AFC = Age at first calving

DIM5 = Days in lactation up to five years of age

DL5 = Number of days lived up to five years of age

FCI = First calving interval

HB = Farms with Holsteins and Brown Swiss

HJ = Farms with Holsteins and Jerseys

HL5 = Herd-life up to five years of age

LAC5 = Number of lactations completed by five years of age

CHAPTER I

Introduction

INTRODUCTION

Dairy breeds have been thoroughly studied with respect to production and type traits, and their performance is acceptably well known. Based on those studies, farmers can select the breed they want according to their target market, i.e. if they want to produce butter or cheese, they might select Jerseys. In the United States, there is an overwhelming majority of Holstein over any other breed. Holsteins might be close to "perfection", but every breed has a comparative advantage. For instance, there might be other breeds with better fertility, or better adapted to heat-stress or other stressful conditions. Overall economic performance could also have a role. There are also personal preferences, and different breed associations are active.

As a result of genetic selection, production traits have greatly increased through time. This transformation of the dairy populations is associated with other changes: Nutrition requirements have been adapted; new facilities, management practices, and utilization of chemicals to further increase milk production or aid in reproduction practices have been established. Contrastingly, scarce or even null improvement has occurred for some other important traits, sometimes called fitness traits, which include fertility and longevity. The dairy industry is presently less concerned about production and focusing more on improving, or at least, preserving, those traits. Fertility and longevity have been suffering a steady detriment partly as a result of the biological strains that the modern cow must now endure. In general, fitness traits have been less studied, and are less heritable; but even when these traits are more dependent on environmental conditions, there still might be definite differences among breeds.

Fertility and Longevity are complex traits that can be evaluated in several ways. Longevity, arguably more complex than fertility, has been least studied. These less heritable traits could benefit from crossbreeding. Nonetheless, crossbreeding without planning could prove disadvantageous. Presently, there are no genetic evaluations for crossbred animals, in part due to technical reasons, since heterosis is not straightforward to model. A careful study among breeds of traits like disease resistance, calving ease, fertility, and longevity is required to give a background for improving present genetic evaluations and to help develop future genetic evaluation strategies for crossbreeding or introgression.

Design experiments are sometimes used for comparison purposes. However, they have the practical disadvantage of losing “external validity”. Experimental conditions are seldom replicated in real life. Therefore, observational studies are justifiable to obtain information to characterize fertility and longevity-related traits, especially when there is an opportunity to have different breeds in a common environment, so the differences observed are truly due to breed, regardless of quality of sires.

Objectives

The general objective of this research was to compare the three most abundant breeds in the United States for some fertility-related and longevity-related traits.

The first particular objective was to evaluate breed differences for heat-stress resistance using age at first calving and first calving interval. The second particular objective was to compare and make inferences about survival-related traits, assessing breed by region interactions for seven regions of the United States, and a final objective was to suggest further lines of research relative to fertility and longevity evaluations.

CHAPTER II

Literature Review

LITERATURE REVIEW

The present dissertation comprises general comparisons of some measurements of fitness traits in three breeds of dairy cows: Brown Swiss, Holsteins, and Jerseys. Brown Swiss are similar to Holsteins in corporal size and inbreeding coefficients. A contrasting breed is Jersey, with a smaller corporal size, higher overall inbreeding coefficient, and milk containing higher amounts of solids. However, a thorough description of the three breeds is superfluous, since their characteristics are well known. A brief review of the fitness traits fertility and longevity, from which some measurements were studied in this work, is probably more useful. Heat stress is included in this review, since it is an important component of the regionalization chosen to study breed by region interactions.

Fertility

Poor fertility increases involuntary culling and replacement costs. It also causes additional management costs due to insemination fees and medical care, and the changes in month of calving may disrupt management plans. Less milk and fewer calves per year are produced. In Great Britain over one-third of culling in dairy herds is due to poor fertility, compared to about 17% due to low milk yield (Ministry of Agriculture, Fisheries and Food, 1984). In the United States, the low average estrous-detection rate (< 50%) in most US dairy herds is a major factor afflicting reproductive efficiency (Lopez, et al., 2004).

Washburn et al. (2002) studied eight 3-year averages of estrus-detection rates, starting for 1976-1978, up to 1997-1999 in Southeastern United States. They found that estrus-detection rates decreased from 1985 to 1999. Estrus detection went from 50.9 to 41.5% in Holsteins, and from 59.6% to 49.5% in Jersey cows. Higher days open started in 1985 for Holsteins, while averages for Jerseys varied little before 1990, but from 1990, days open for Jerseys increased rapidly. Jerseys increased 30 d, and Holsteins increased 44 d of days open for the total period studied. Breed by time interaction was significant for the early averages, but days open have been almost parallel in both breeds from 1991 to 1999. Services per conception increased from 1.91 to 2.94 in the same time-span for both breeds. When the data were analyzed for five subregions, each one including from one to three states, Washburn et al. (2002) found differences in mean days open and services per conception across subregions, but the changes in those measures through time were similar. Therefore, there was no subregion by time interaction.

Loss of fertility could partly be due to increasing degrees of inbreeding. Cassell et al. (2003) found negative effects of inbreeding on fertility. Inbreeding levels had increased geometrically in Jerseys due to limited number of sires and close relationship among sires (Thompson et al., 2000a). When different objectives for selecting sires were used in a simulation program designed to select individual mates for Jersey cows, predicted inbreeding ranged from 6.1 to 10.7% (Tozer and Stokes, 2002). Careful consideration of objectives could help minimize problems due to inbreeding.

Washburn et al. (2002) reported that while fertility declined, milk production increased from 4753 ± 105 Kg to 6375 ± 105 Kg for Jerseys (34%), and from 6802 ± 24 Kg to 8687 ± 24 Kg (27.7%) for Holsteins from 1976 to 1999. Genetic correlations between fertility and milk production are negative (Kadarmideen, et al., 2003), and high milk yields reduce estrus time (Lopez, et al., 2004). National evaluations (USDA, AIPL site, 2004) also show these trends: Figure 1.1 shows declining phenotypic trends for daughter pregnancy rates in Holstein, Brown Swiss and Jersey cows, and Figure 1.2 shows the phenotypic increase in milk production (For the current, November 2004, the milk averages used for genetic evaluations in USDA are: 8798 Kg for Brown Swiss, 10,627 Kg for Holstein, and 7296 Kg for Jersey cows). Breeding values for milk and daughter pregnancy rates in Holstein cows and sires are presented in Figures 1.3 and 1.4. Milk production has been increasing linearly, but at the same time, fertility, measured as daughter pregnancy rates for the national evaluations, has been decreasing equally linearly.

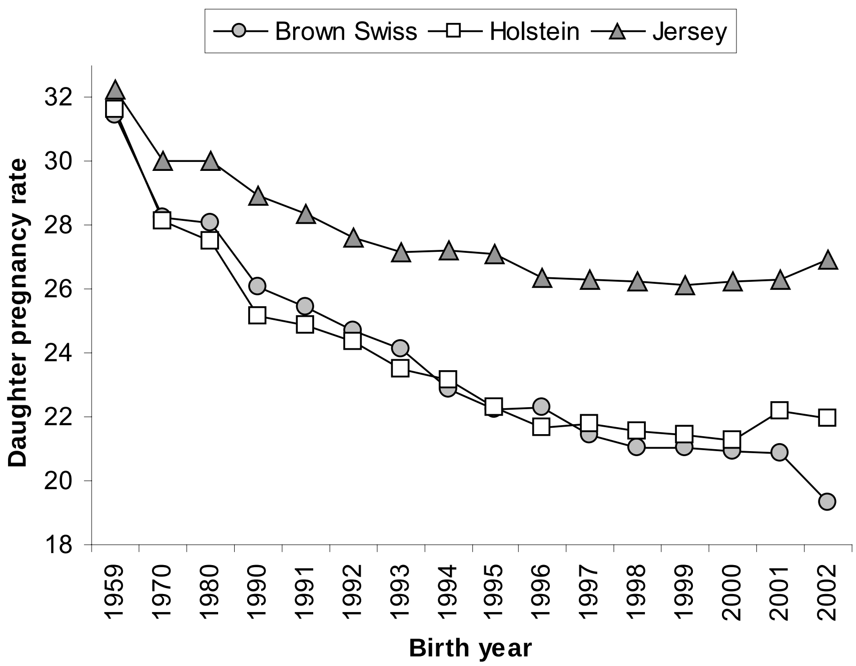


Figure 1.1 Daughter pregnancy rates for Brown Swiss, Holstein, and Jersey cows (USDA, November 2004 evaluation).

For Figures 1.1 and 1.2, the first three years were graphed to serve as reference, and represent data obtained approximately every decade. In the first decade, there was a steep drop in pregnancy rates (Figure 1.1). For the decade 1970-1980, pregnancy rates seemed to stabilize in the three breeds, but the rates dropped again for 1990. Phenotypic pregnancy rates have been declining since 1990. If the results for 2000 had been drawn right after those for 1990, it would be clear that phenotypic pregnancy rates were declining at the same rate as in previous decades, even for Jerseys that have a less steep drop of fertility trend. For Holstein cows born in 2001, and Jerseys born in 2002, phenotypic pregnancy rates seemed to stabilize (Figures 1.1). Cows born in those years were evaluated most probably for their first pregnancy, when fertility is better (Rajala-Schultz and Fraser, 2003). This could be the reason for an improvement of the fertility trait.

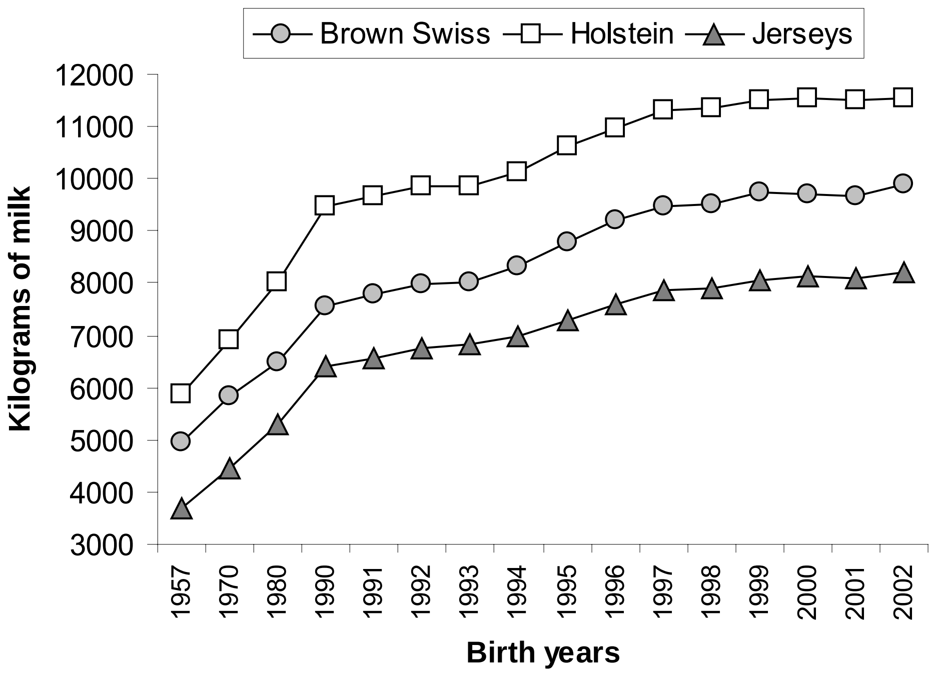


Figure 1.2 Phenotypic trend for milk yield (pounds) in Brown Swiss, Holstein and Jersey cows (USDA, November 2004 evaluation).

Another reason might be that cows have been responding to selection for fertility. Breeding values for daughter pregnancy rates in Holstein improved for the latest birth years (Figure 1.4). However, no breeding value improvement is apparent for Brown Swiss, and unclear results appear for Jerseys (Figures 1.5 and 1.6). Younger sires have, necessarily, younger daughters. Therefore, more accurate results of the selection for fertility have to wait for further evaluations. Reliabilities for pregnancy rates have never gone above 0.34 for any breed (USDA, AIPL site, 2004).

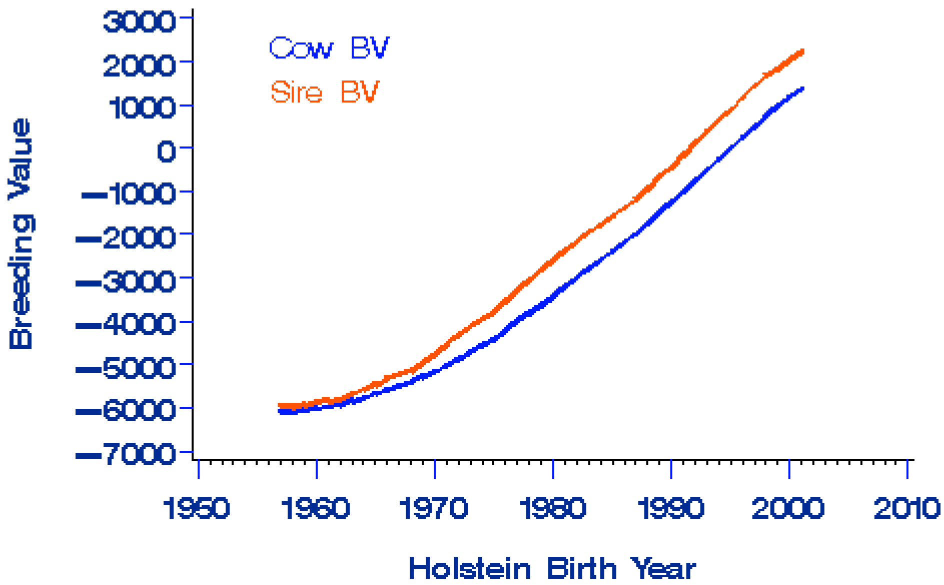


Figure 1.3 Trend in milk breeding values for Holstein. Calculated November, 2004. USDA.

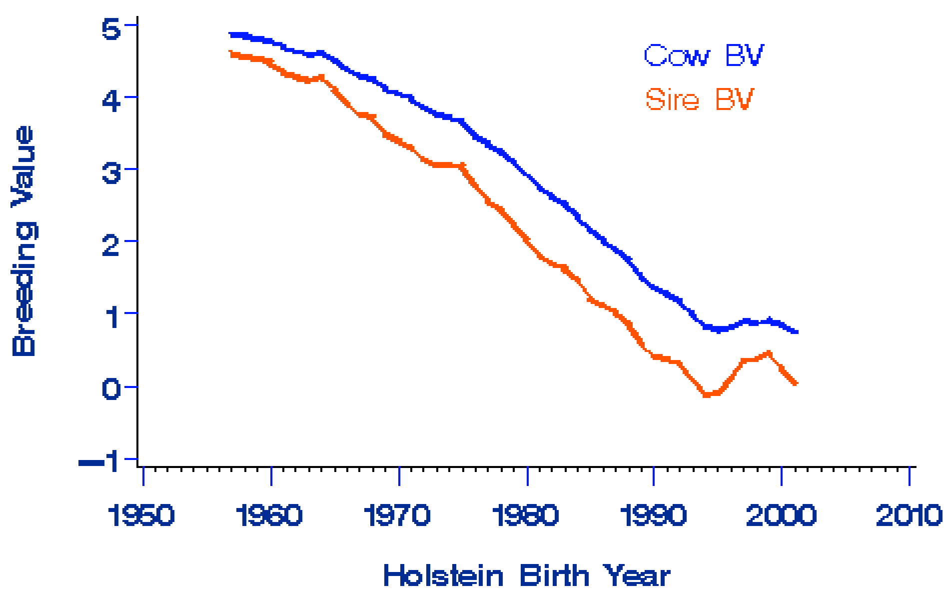


Figure 1.4. Trends in daughter pregnancy rates breeding values for Holstein. Calculated November, 2004. USDA.

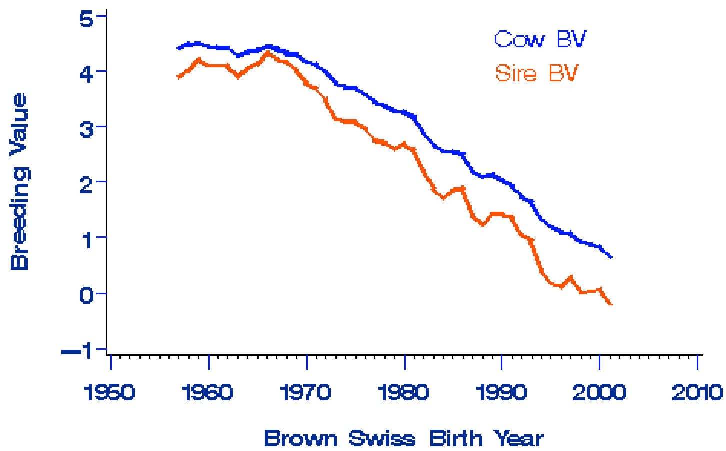


Figure 1.5. Trends in daughter pregnancy rates breeding values for Brown Swiss. Calculated November, 2004. USDA.

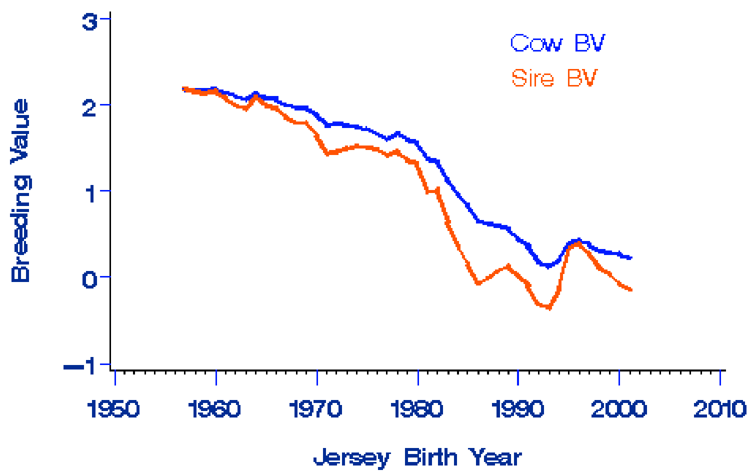


Figure 1.6. Trends in daughter pregnancy rates breeding values for Jersey. Calculated November, 2004. USDA.

Pregnancy rate evaluations were included in the selection indexes for fluid, cheese, and net merit in use in the United States in 2003 (VanRaden, 2004). Pregnancy rate is defined as the percentage of non pregnant cows that become pregnant every 21-day period, corresponding to one reproductive cycle in cows (VanRaden et al., 2003). Pregnancy rate is related to days open as follows:

Pregnancy rate = 21/(days open - voluntary waiting period + 11)

In this equation, voluntary waiting period is assumed to be 60 days. The United States national fertility evaluation is based on pregnancy rate. For this evaluation, the date of pregnancy is estimated by the date of calving minus gestation length or last reported breeding date, and days open are converted to pregnancy rates using the linear formula: 0.25(233-days open). Predicted transmitted abilities are obtained using an Animal Model (VanRaden et al., 2004).

Another measure of fertility is calving interval. It consists of three stages: a) From calving to end of voluntary waiting period, b) from end of voluntary waiting period to conception, and c) from conception to end of pregnancy (on average 280-290 d, depending on breed). Stages a, and b form days open. A minimum or null stage b is desirable to maximize reproductive efficiency. Several other traits can be used to evaluate fertility, including (but not limited to) interval from calving to first service, calving to conception, conception success to first service, and number of services per conception. Kadarmideen, et al. (2003) found heritabilities of fertility traits from 0.012 to 0.028, permanent environmental variance was 0.016 to 0.032. The genetic correlations among fertility traits were high (> 0.70).

One measurement of fertility that has not been studied thoroughly in the United States is age at first calving. In a study in California with Holstein heifers, first calving at < 23 mo was associated with reduced yields of milk and milk components. Cows in the older age group (> 25 mo) produced more milk fat and true protein than cows in the medium and youngest groups. Incidence of stillbirths was highest for cows in the low group (19.8%). Days open, number of inseminations, incidence of mastitis and lameness was lowest for cows in the medium group (23 to 25 mo). Among heifers that died, cows in the youngest group tended to die earlier postpartum than cows in the oldest group (Ettema and Santos, 2004). In a recent study, Muir at al. (2004) found that cows with younger ages at first insemination were more likely to have dystocia, and the genetic correlation between age at first calving and dystocia was -0.35 ± 0.06.

Nilforooshan and Edriss (2004), studying Iranian Holsteins, found that the optimum age at first calving to maximize first lactation ME milk yield, was 24 mo. Heifers with lower weights were less likely to get pregnant (Torell et al., 1998, Vargas, et al., 1998). However, Durr (1997) found that older ages at first calving increased the risk of culling. Puberty is directly related to the weight of the heifer, not to her age. Therefore, optimum nutrition to insure proper growth and weight at first breeding is essential. In general, emphasis in nutrition is advised to improve fertility. Full grown Jersey cows on average weight 454 Kg (range: 364 to 545 Kg), while Holsteins and Brown Swiss weight around 680 Kg (Oklahoma State University, 1995-2002). Thus, the optimum weight at first insemination for the three breeds differs, since the minimum weight advised is when heifers are 2/3 of their mature weight. Muir et al. (2004) found that heritability of age at first insemination was 0.19. Therefore, age at first insemination would respond to selection.

Fikse, et al. (2003) investigated genotype by environment interaction for several traits across countries. They defined interaction as a change of scale or re-ranking of animals in contrasting environments. They defined contrasting regions in Australia, Canada, USA, and Republic of South Africa. Age at first calving and rate of maturity showed significant genotype by environment interaction. Furthermore, inside the United States, Castillo-Juarez, et al. (2000) found genotype by environment interactions for mature equivalent milk yield and lactation mean somatic cell scores, and for mature equivalent milk yield and conception rates at first service in low and high-environment herds. Genetic correlations between pairs of traits were consistently smaller in high environment herds, suggesting that better management lessens the antagonistic genetic association between milk yield and mean somatic cell score and conception rates at first service (Castillo-Juarez, et al., 2000).

Contrasting environments should form regions. However, there is presently no clear agreement among authors as how to regionalize the United States, and different studies have used different regional definitions. Moreover, even if weather is the main objective to form regions, several different partitions can be made, depending on the variables included (rainfall, temperature, relative humidity, temperature-humidity indexes, and/or vegetation-types, for example) and when or how these variables are to be measured, i.e. maximums, minimums or averages ((David A. Wert, National Weather Service, Blacksburg, VA, 2004 personal communication). Regardless of how regions are defined, genotypes by environment interaction studies are clearly justified.

Heat-Stress

Heat-stress can be defined as the additional effort to maintain internal thermo-neutrality when the environment is too warm. Humidity influences the degree of heat-stress. Thermo-neutrality is essential for the proper function of metabolism in general. On an ambient temperature ranging from about 10^{o}C to 22^{o}C, no additional energy is used to heat or cool a dairy cow's body, Heat seems more stressful than cold in dairy cattle. In a series of studies in Finland, colder facilities did not significantly affect cows for reproductive disorders (ketosis, mastitis, metritis, parturient paresis and ovarian disorders) (Schnier, et al., 2002a) or for reproductive performance (days from calving to first service, first service pregnancy risk, and repeated-service-conception hazard) (Schnier, et al., 2004). However, cows housed in cold environments produced 11 kg less of milk per test-day than cows kept in a more thermo-neutral environment (Schnier, et al., 2003), probably due to cold-stress.

Contrastingly, heat stress depresses fertility and production in lactating dairy cows. Lopez-Gatius (2003), in a study of Holstein cows in northeastern Spain from 1991 to 2000, divided the years into warm and cool periods, and data were obtained from cows periodically examined by the author. Cyclicity and pregnancy rates corresponding to the warm period significantly decreased over the 10 year period, yet remained practically constant during the cool period. Ovarian cysts were more frequent during the warm (12.3%) than during the cool (2,4%) period. Lopez-Gatius (2003) found a decrease of 6% for pregnancy rate, 7.6% in cyclicity, and an increase of 8% of inactive ovaries in the warm period, per each 1000 kg increase in milk yield.

The likelihood of ovulation can be reduced from 91 to 18% comparing cows in a thermo neutral environment with cows undergoing heat stress (Wilson et al., 1998), and the cleavage capacity of oocytes is reduced during the summer months (Al-Katanani, et al., 2002). Heat-stress effects on fertility have been recently reviewed by Jordan (2003).

Milk production is impaired by heat stress, even if it is moderate and for only a few days (Ominski et al., 2002). This is partly because energy requirements increase for the cow's body to endure heat-stress (West, 2003), but at the same time, reduced dry matter intake occurs (Zoa_Mboe, et al., 1989, Holter, et al, 1997, Ominski et al., 2002, and West, 2003, for example). In Australia, Mayer et al. (1999) found that production decline is affected by factors such as location, the production potential of the cow, and management. In this latter respect, the use of heat control systems like fans, sprinklers, shade structures, or combinations of these, reduced heat stress (Armstrong, 1994). However, even when cooling systems are used in dairy farms, fertility often remains low (Wolfenson et al., 2000, Al-Katanani, et al., 2002).

Campos, et al. (1994) evaluated genetic parameters for milk yield, milk constituents, and several reproductive traits in Holstein and Jersey first lactation cows in Florida, a subtropical environment. Heritabilities ranged from 0.27 to 0.43 for yield, 0.38 to 0.51 for milk components, and 0.025 to 0.056 for reproduction traits (6 estimates: calving interval, days open, and number of services per conception in Jerseys and Holsteins). Correlations of breeding values between yield and reproduction traits were low and generally antagonistic. These findings are similar to estimates obtained in temperate areas. For example, in a recent study (Muir at al., 2004) found Heritabilities for calving interval equal to 0.07 and for non-return rates from 0.021 to 0.024. Farmers would try to time cows to avoid breeding or top production under hot conditions, but the duration of lactation makes it difficult to avoid heat stress; thus, regardless of insemination season, cows will be lactating under hot conditions in most regions of the country for a period of their lactation. Several states with large cow populations, like Arizona and Texas, have overall warm climate with severely hot summers.

Another important fitness trait that has been declining as milk production has been increasing is longevity. Some longevity-related traits were examined in the present dissertation, and a brief review follows.

Longevity

Longevity has one of the highest impacts on herd profitability after milk production (Durr, 1997). Profit is defined as the difference between total revenues and total costs. If culling is voluntary, the cow is culled because a replacement cow is expected to be more profitable, rather than because she is not able to produce profitably (Lehenbauer and Oltjen, 1998). Low milk yield is traditionally accepted as the only true reason for voluntary culling. However, Bascom and Young (1998) found that production is usually the second reason for culling; reproduction the first, and mastitis the third. Hadley (2003) mentions that there is more health-related culling than culling due to low production. Besides, he states that culling due to health problems (including mastitis) increases with parity (Figure 1.7), and presents data showing that somatic cell counts, which are an indirect indication of mastitis, increase throughout the lifetime of cows (Figure 1.8). It is possible that this increment be related to the health-culling trend. Hadley (2003) also mentions that maximum milk production is achieved around the third and fourth lactation, yet culling for production increases slightly, but steadily, throughout the life of the cow (Figure 1.8) as new generations of cows produce more due to genetic improvement.

If culling (for whatever reason) occurs before the second lactation, the producer loses the natural milk increase due to parity, and when cows do not live past their second lactation, they do not have the opportunity to pay for their raising costs with milk production. Weigel, et al. (2003) found that cows that received better management in the form of fewer cows per employee, greater percentage of labor supplied by family members, herds with fans, sprinklers, self-locking manger stalls, palpation rails, and maternity pens had a significantly lower risk of involuntary culling than cows in herds without such assets. Therefore, improving management should be a good investment.

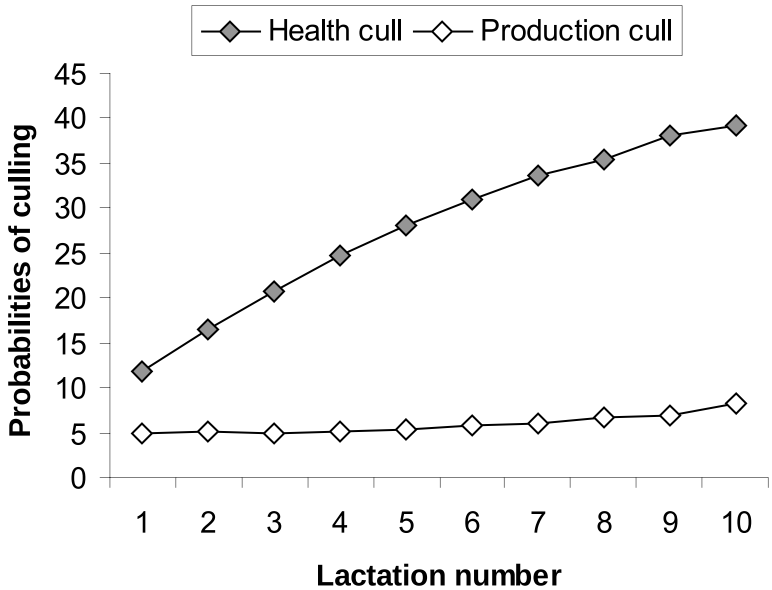


Figure 1.7. Impact of parity on probabilities of culling (percent) for health or for production (Adapted from Hadley, 2003).

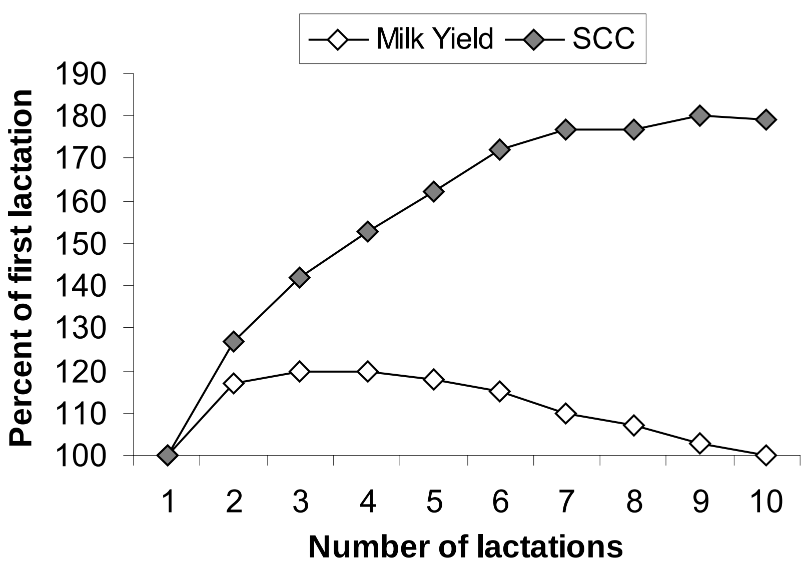


Figure 1.8. Impact of parity on milk and somatic cell counts (Adapted from Hadley, 2003).

Another factor that influences involuntary culling is inbreeding. Inbreeding results in decreased survival in Holsteins and Jerseys (Thompson, et al., 2000a and b). Inbreeding readily disappears by crossbreeding. In the United States, the results of a survey indicated that the most common first generation crosses were between Jersey and Brown Swiss bulls mated to Holstein cows, backcrossing to either parental breed in the next generation. Producers indicated they achieved improvements in fertility, calving ease, longevity, and milk component percentages. However, they had problems marketing crossbred breeding stock and bull calves, and the lack of uniformity of females created management challenges (Weigel and Barlass, 2003). General heterosis was between 3.4 to 4.4% of the purebred mean for yield traits, but was only 1.2% of the purebred mean for Productive Life, and practically null for somatic cell scores (VanRaden and Sanders, 2003).

Genetic evaluations for somatic cell scores (SCS) and productive life (PL) (10 mo of days in milk up to seven years of age of the cows) have been available in the United States since 1994. In 1999, PL and SCS were added to the Cheese Net Merit and Fluid Merit indexes. In 2000, the merit indexes were revised to include linear conformation composites (VanRaden, 2004). Conformation traits (Schneider, 2003) and SCS (Neerhof, et al., 2000) have and impact on longevity, thus, by including those traits, the evaluation for longevity is enhanced (longevity estimated by PL). Figures 1.9 and 1.10 show the phenotypic trends for SCS and PL graphed from USDA evaluations for November, 2004. The corresponding genetic trends are shown in USDA website, and show erratic trends for the three breeds for SCS, and positive trends for PL, using data from cows born since 1960.

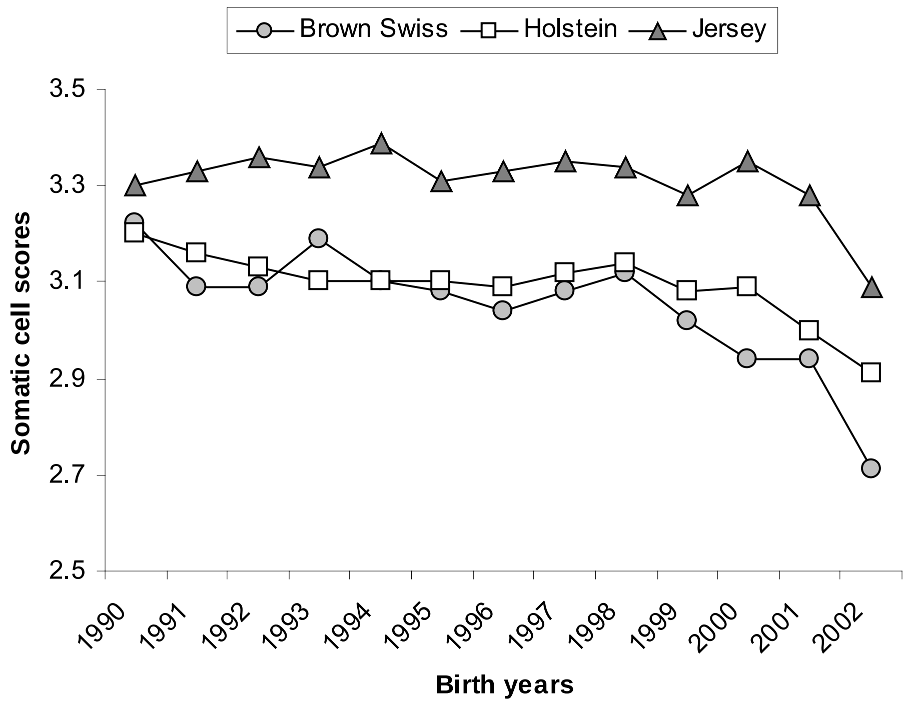


Figure 1.9 Phenotypic trend for somatic cell scores in Brown Swiss, Holstein and Jersey cows born from 1990 to 2002 (USDA, November 2004 evaluation).

Figure 1.9 shows a decline in somatic cell scores for cows born in the latest 2 to 4 years (2 for Jerseys, 3 for Holsteins, and 4 for Brown Swiss). This desirable trend is most probably due to the early parity results of the cows evaluated, and not to a response to selection. A slight decrease in SCS can be noticed for Holsteins and Brown Swiss for the period graphed, but not for Jerseys.

A similar scenario is apparent in Figure 1.10, where PL seems to have increased for Holsteins born in 2000 and 2001. This is partly the result of still incomplete evaluations for those cows (PL comprises seven years), but PL genetic trend has also been improving: USDA reports a genetic increment from four to seven mo, depending on breed, since 1960 (USDA, AIPL site, 2004). The larger phenotypic values of PL for Jerseys represent only about 4 mo with respect to Holsteins, and 3 mo with respect to Brown Swiss. Genetic values for PL are less than a month larger for Jersey than Brown Swiss' or Holstein', Jersey's phenotypic PL trends seem to be decreasing for the most recent complete evaluation (cows born in 1997).

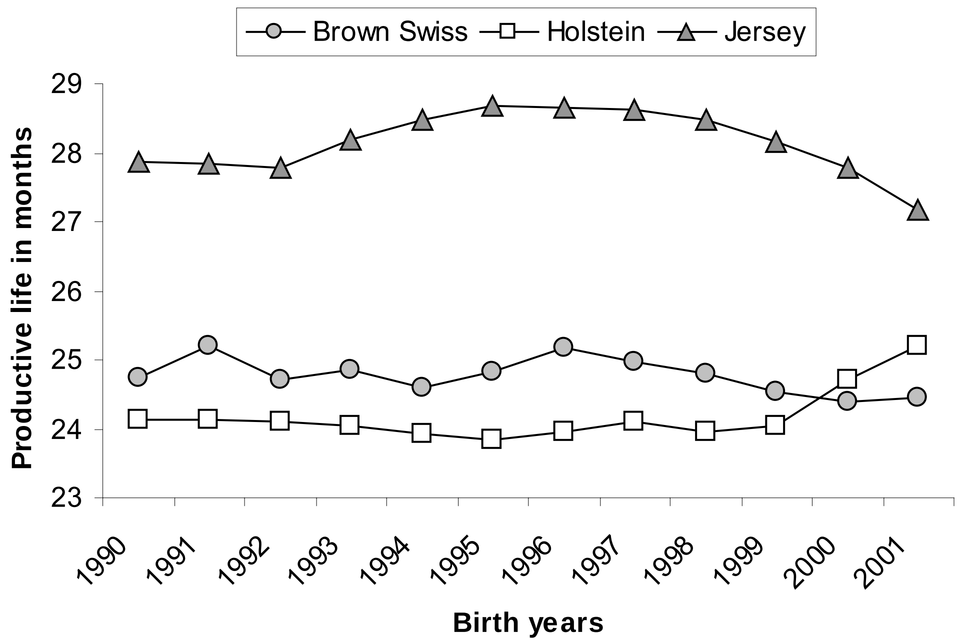


Figure 1.10 Phenotypic trend for productive life in Brown Swiss, Holstein and Jersey cows born from 1990 to 2001 (USDA, November 2004 evaluation).

Longevity, defined as the total time a cow lives, is a long-term trait that is expressed only once, at the very end of life, and is influenced by a variety of factors both intrinsic and extrinsic to the cow. Examples of the former are health status, fertility, production level, and age, while factors extrinsic to the cow include milk prices, space available in the farm, replacement heifer inventory, weather, and so on. Moreover, influences on a given cow are likely to change as she ages, since herd is a dynamic entity, and contemporary groups change due to different calving intervals and culling rates of herd mates (Ducrocq, 2001).

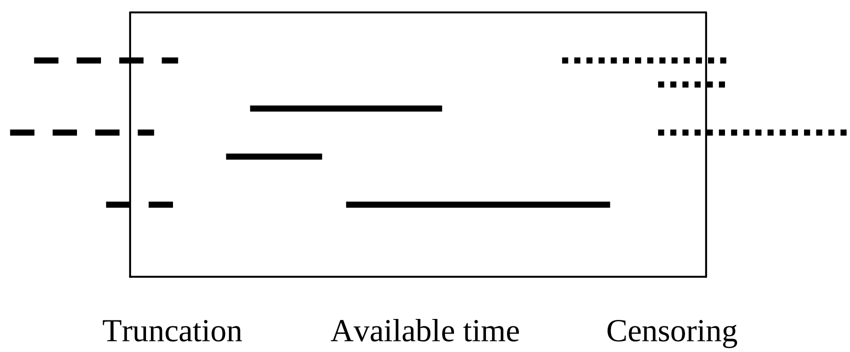
Table A. Longevity-related traits and methodologies (Selected references from Durr, 1997).

Van Doormaal et al., 1985	Stayability up to 17 mo of herd-life Stayability up to 55 mo of herd-life	Linear models/ Henderson Method III
DeLorenzo and Everett, 1986	Stayability up to 41 mo of age Stayability up to 54 mo of age	Logistic models
Dentine et al., 1987	Percentage of cows culled Age at last record Stayability up to 84 mo of age	Linear models
Ducrocq at al., 1988	True herd-life (days) Functional herd-life	Survival analysis
Harris, 1989	Survival rate	Linear models
VanRaden and Klaaskate, 1993	Total mo in milk by 84 mo of age	Linear models
Jairath et al., 1994	Lifetime days in milk Number of lactations	Linear models
Vukasinovic et al., 2001[1]	Functional herd-life	Survival analysis

[1] Added to Durr, 1997

Longevity has been evaluated using a variety of methodologies, including logistic analysis, linear models, and survival analysis (Cox and Weibull models), and for different longevity-related traits. Some studies have used linear models for binary outcomes, even when that is theoretically incorrect, since for such outcomes the residuals are not independent and identically distributed $N(0, \sigma^2)$, an assumption for linear models. A sample of longevity-related traits analyzed is presented in Table A.

In recent years a set of statistical programs, the Survival Kit, was developed to perform Survival Analysis in an animal breeding context (Ducrocq and Solkner, 2000). Several countries around the world, such as Australia, France, Germany, The Netherlands, and Italy, are presently evaluating longevity with this methodology. Survival analysis is a family of nonlinear statistical procedures that model the time elapsed between two events. Survival analysis can consider time-dependent covariates, meaning that it is not necessary to assume that all effects fitted remain constant over time or be completely random. Survival analysis can fit both time-dependent and time-independent covariates. Censored data can also be included. A graphic illustration of censored data follows:



The box represents the available time for the study. Many cows would have been born before that allowable time, represented by the discontinuous lines on the left. Since contemporary groups and general conditions would be unknown, those records (called truncated or left-truncated) would have been discarded when using linear models. Some other cows would still be alive at the end of the study, and they could be culled right after the end of the study or live for a long time. Unless projected, such data cannot be used either, because the outcome was not observed. Such data are called censored or right censored. The only useful data would then be the dark continuous lines (adapted from Ducrocq, 2001).

The models most frequently used in survival analysis are called Proportional Hazard models, because the hazard of one subject is always proportional to that of another. Any level can be set as reference without loss of generality. The term hazard refers to the relative risk of an event. For example, if two cows have hazards of 0.5 and 1.5 (for any event), the latter cow is three times as likely to incur in the event as the former cow, and the hazard ratio of relative risk would be 3. The proportional hazard (or instantaneous rate) of some event (known as hazard function for survival analysis) at time t is represented by:

$$\lambda(t{:}w) = \lambda_0(t)\exp(w'\mathbf{B})$$

where $\lambda_0(t)$ is the baseline hazard function or average hazard at time t. This baseline can remain unspecified when using a Cox model (non parametric), or can have a specific parametric distribution, which in animal breeding is usually Weibull. w is a vector of covariates, and **B** is a vector of regression coefficients. If a Weibull hazard function is used, then the baseline can be summarized by two parameters: ρ and λ, for shape and scale, respectively (Grohn at al., 1997). The Weibull distribution can take a wide variety of hazard-rate curves, depending on the values of those two parameters. The exponential distribution is a special case of Weibull when $\rho = 1$.

Survival analysis also accounts for the skewed distribution of survival data, and can treat one fixed effect as a stratification factor.

Recently, longevity breeding values have been calculated for Holstein and Jersey sires in the United States using survival analysis (Caraviello, et al., 2004a and b). For Holsteins, they used the nine regions of the National Weather Service in the United States, in a Weibull proportional hazards model. Longevity was defined as the number of days from first calving until culling or censoring. Sire variances and parameters for the Weibull were calculated for each region separately. There were differences in variances and parameters among regions, and the authors concluded that a single national ranking for sires' breeding values for longevity would not be appropriate (Caraviello, et al.2004a).

Survival analysis techniques may also be used to model the reproductive performance of dairy cows, i.e. when reproductive efficiency is measured using conception as an outcome, performance may be overestimated if information is excluded from the analysis for cows that would be eligible for breeding but were culled. By including data from censored cows, improved estimates of reproductive performance might be obtained (Lehenbauer and Oltjen, 1998).

There are several other methods to estimate longevity, including discrete-time and continuous-time methods. Sometimes these methods are complementary because they can answer different questions (Allison, 1995). The analysis of discrete data can be done with the GENMOD procedure in SAS (R). An advantage of the GENMOD procedure, with respect to other similar procedures in SAS ®, is that it gives likelihood-ratio-chi-square statistics and can fit interaction terms in the model. This procedure is used for analyzing generalized linear models. Generalized linear models are a broad class of models (of the exponential family) that can be analyzed by a unified approach. GENMOD can be used for binary outcomes (0/1) or for count data by specifying the link function and the distribution to be used. For logistic analysis the distribution to be used is the Binomial with the logit as the link function. For count data, the distribution of choice would be Poisson, with log as the link function (Stokes, et al., 2000). The binomial distribution models the probability of p "successes" in n independent trials, assuming that the probability p on each trial is constant. With a large sample size, it can be approximated by the Normal or by the Poisson distribution. The Poisson distribution represents the number of occurrences over constant areas, volumes, or times. These distributions are frequently used in quality control, reliability and animal breeding.

In the present dissertation, longevity-related traits were studied for the first five years of life of cows of three breeds using categorical and linear model analyses, performed on SAS ® and the Survival kit.

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CHAPTER III

Manuscript 1

Comparisons of Holsteins with Brown Swiss and Jersey Cows on the Same Farm for Age at First Calving and First Calving Interval

ABSTRACT

Our objective was to evaluate breed differences for heat-stress resistance as reflected by age at first calving and first calving interval. We examined the effect of geographic location and birth season on age at first calving, and geographic location and first calving season on first calving interval on Holsteins and Jerseys, and Holsteins and Brown Swiss located on the same farm. We defined seven regions within the United States: Northwest, Central north, Northeast, Central, Central south, Southwest and Southeast, and also analyzed seven individual states: Ohio, Wisconsin, Oregon, California, Arizona, Texas, and Florida. Brown Swiss were older ($P < 0.01$) than Holsteins at first calving (833 ± 2.4 d vs. 806 ± 2.0 d in regions, and 830 ± 3.1 d vs. 803 ± 2.4 d in states), but Holsteins and Brown Swiss did not differ for first calving interval. Jerseys were younger than Holsteins at first calving and had shorter first calving intervals ($P < 0.01$). In data from individual states, Holsteins housed with Brown Swiss were older ($P < 0.01$) at first calving than Holsteins housed with Jerseys (800 ± 2.7 d vs. 780 ± 2.5 d). Holsteins housed with one breed or the other were analyzed as a separate dataset, and referred to as "type of Holstein". The interaction of "type of Holstein" with first calving season was highly significant ($P < 0.01$) for first calving interval. Geographic location and season effects were smaller for Jerseys than for Holsteins; thus, Jerseys showed evidence of heat-stress resistance with respect to Holsteins. Management modified age at first calving in Holsteins to more nearly match that of the

other breed. Longer calving intervals might be partly due to voluntary waiting period to breed the cows.

(**Key words:** breed comparison, age at first calving, first calving interval, heat-stress resistance)

Abbreviation key: AFC = age at first calving, **FCI** = first calving interval, **HB =** farms with Holsteins and Brown Swiss, **HJ** = farms with Holsteins and Jerseys.

INTRODUCTION

Fertility in cows of all dairy breeds has diminished over time in the United States (VanRaden et al., 2003). Lopez-Gatius (2003) reported similar fertility trend for Holstein cows in Northeastern Spain, but fertility was most affected under heat-stress conditions at breeding. Heat-stress disrupts reproduction in dairy cattle (Kadzere et al., 2002), and is a known problem in regions with warm or hot climate, especially if ambient humidity is high. The United States have been subjectively partitioned to account for regional differences in production, reproduction, and health traits, and for genetic evaluations (Norman et al., 1995; Norman et al., 2000; Oseni et al., 2003; VanRaden et al., 2003; Wiggans and VanRaden, 1991; Zwald et al., 2003). VanRaden et al. (2003) divided the country in five regions for USDA daughter pregnancy rate evaluations, and mentioned that the main differences in days open by month of calving occurred in the Southeast. Zwald et al. (2003) used a similar division for sire evaluations, but divided the Midwest and Southeast into Central north, Central, Central south and Southeast. These regions are likely to produce little heat-stress year-round (Central north), heat-stress during summers (Central), heat-stress with low humidity (Central south), and heat-stress with high humidity (Southeast)

(David A. Wert, National Weather Service, Blacksburg, VA, 2004 personal communication).

Seasonal heat-stress may have an impact on reproductive performance even in temperate regions. For example, Alnimer et al. (2002) found that pregnancy rate was higher for cows inseminated in winter (average daily ambient temperature of 10.9 ^{o}C) than in summer (average daily ambient temperature of 20.2 ^{o}C) using Italian data. The season of birth of the cow can affect milk production (Barash et al., 1996). Season of birth could also affect age at first calving (**AFC**) because energy requirements of the calf to maintain thermo-neutrality increase with heat-stress. At the same time, DMI diminishes. Such effects could delay onset of puberty and increase AFC (Fox and Tylutki, 1998). The effect of birth season on first calving interval (**FCI**) has not been reported.

Age at first calving and FCI of cows impact profitability (Tozer and Heinrichs, 2001), but AFC has not been widely studied, even though there is evidence that it influences milk production and survivability (Durr et al., 1999). Rajala-Schultz and Frazer (2003), using data from Ohio, found that days from calving to conception increased in cows from 1992 to 1998, but remained stable for heifers. Age at first calving and FCI can be used to evaluate reproductive performance under heat-stress.

Comparison of breeds for fertility is justified at an intra-herd level because reproductive traits are highly influenced by management (Castillo-Juárez et al., 2000). In this study we used only farms with two breeds of cows, i.e. farms with Holsteins and Jerseys (**HJ**) and farms with Holsteins and Brown Swiss (**HB**).

The objective of this study was to evaluate breed differences for heat-stress resistance by analyzing the effects of geographic location and birth season on AFC and the effects of geographic location and season of first calving on FCI on Holsteins and Jerseys, and Holsteins and Brown Swiss housed in the same farm. The United States was partitioned in seven regions, and seven states were studied individually for geographic location effects. Similar climatic conditions were assumed within regions or states, and cows of different breed in the same farm were assumed to face the same environmental conditions.

MATERIALS AND METHODS

Data were provided by the Animal Improvement Programs Laboratory (**AIPL**), USDA, consisting of records with calvings from January 1, 1995 to June 30, 2001. Data from Brown Swiss and Jersey cows were merged with Holstein data when they had the same DHI herd codes. We also merged Brown Swiss or Jersey with Holstein cows when herd codes were different, but the farm address was the same. Two data sets resulted: one with HJ and one with HB farms.

The majority of the farms with two breeds had only a few cows of one breed. For such farms, breed, region, and season effects would be poorly estimated. Herd-year-season breed groups of three or more cows were required, but most of the farms included had more cows of each breed. Studies of FCI requires cows that survive to calve a second time, while AFC only requires that cows calve once. In this study we used the same cows for both traits. The impact of requiring a second calving on AFC is unknown. The data used were restricted to cows with their first two calvings on the same farm with at least 310 d between calvings. Prior to edits, data included 178,090 cows in 1387 herds with Holsteins and Brown Swiss with at least 5 cows per breed. These farms had only 5.2 % Brown Swiss cows. After edits there were 8273 cows in 150 HB farms with 25.6 % of Brown Swiss cows. There were 222,528 cows in 2117 Holstein-Jersey farms with 12.8 % of Jersey cows before edits, and 17,492 cows in 219 HJ farms with 38.2 % Jerseys after edits.

In a preliminary study we fitted birth season and birth year for analysis of FCI. We found that birth season did influence FCI, but through an indirect relationship to season of first calving. The season of birth influences the insemination season, but the conception season determines the calving season. We chose to report only the effect of first calving season on FCI.

States included in this study from the seven regions of Zwald, et al. (2003) are:

1. Northwest: Idaho, Washington, and Oregon,
2. Central north: Michigan, Wisconsin, Iowa, Minnesota, and South Dakota,
3. Northeast: Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Delaware, Maryland, and Vermont,
4. Central: Ohio, Indiana, Illinois, Kansas, Nebraska, Missouri, Kentucky, Tennessee, Virginia, and West Virginia,
5. Central south: Texas, Oklahoma, and Louisiana,
6. Southeast: Florida, Georgia, South Carolina, North Carolina, Alabama, Mississippi, and Puerto Rico.
7. Southwest: Colorado, New Mexico, Arizona, Utah, and California.

Seven states were analyzed separately for each dataset: Wisconsin, Ohio, Oregon, California, Arizona, Texas, and Florida. These states were chosen because they have temperate, warm-humid, and warm-dry climates, and both types of farms, i.e. HB and HJ, with reasonable numbers of Brown Swiss and Jerseys, and contained about 64% of the data. The number of herds and cows per region and state are presented in Tables 1.1 and 1.2.

Analyses were performed on each breed combination dataset separately. The models were:

$$Y_{ijklmn} = \mu + b_i + r_j + s_k + br_{ij} + bs_{ik} + yr_l + h(r)_m + \varepsilon_{ijklmn}$$

Where: Y = age at first calving or FCI,

μ = the general mean,

b = breed, i.e. either Holstein and Brown Swiss, or Holstein and Jersey,

r = geographic location, i.e. either regions or states,

s = birth season of the cow when analyzing AFC, or first calving season, when analyzing FCI. Seasons were defined as spring (March to May); summer (June to August); fall (September to November), and winter (December to February).

yr = year of birth of the cow for the analysis of AFC, or year of first calving for the analysis of FCI,

h = herd, nested in r,

ε = the residual, assumed ~ N $(0, \sigma^2)$.

An additional dataset with Holsteins from both types of farms was created and analyzed for the states with the same model, but with herd nested in state by "type of Holstein" (Holsteins in HJ farms and Holsteins in HB farms).

Data were analyzed using the MIXED procedure in SAS, with the probability differences between least squares means tested using the Tukey-Kramer option.

RESULTS

General *P*-values of the analyses are mentioned at the beginning of each section. Tests of differences between breeds, within regions or states, and within seasons are presented in Tables 1.3 to 1.8. The *P*-values obtained between regions or seasons, within breeds, are mentioned when appropriate.

Holstein and Brown Swiss

Age at first calving. In the analysis by regions, breed, geographic location, and the interaction of breed by geographic location were significant ($P < 0.01$). Birth season was not significant ($P = 0.11$), but breed by birth season ($P = 0.01$) was. In the analysis by states, all the effects were highly significant ($P < 0.01$). At first calving, Brown Swiss were older than Holsteins. Table 1.3 shows that breed differences were not significant in the Northwest, the Southeast or for the herds in Oregon, Arizona, and Florida. Table 1.4 shows that Brown Swiss were 18 to 25 d older for AFC than Holsteins for birth seasons other than fall. For cows born in fall, the differences between breeds were 36 d in regions and 43 d in the states, making the interaction of breed by birth season significant.

First calving interval. In the analysis by regions, the effects of geographic location and first calving season were highly significant ($P < 0.01$). The maximum FCI occurred in the Southeast and when cows calved in spring, and the minimum in the Southwest and when cows calved in fall. Breed and the interactions of breed by region were not significant. Breed difference approached significance in the Southeast ($P = 0.08$), with 22 d shorter FCI for Brown Swiss than for Holsteins (464 ± 9.0 d for Holsteins vs. 442 ± 10.8 d for Brown Swiss). In the analysis by states, the effects of geographic location ($P < 0.01$), first calving season ($P < 0.01$), and the interaction of breed by first calving season ($P < 0.01$) were significant. Brown Swiss' shorter FCI than Holsteins approached significance for cows first calving in summer ($P = 0.07$), and in Florida ($P = 0.09$), with Brown Swiss having 27 d shorter FCI than Holsteins (436 ± 10.0 d vs. 409 ± 15.8 d).

Holstein and Jersey

Age at first calving. In the analysis by regions, all the effects were significant ($P < 0.01$) except breed by geographic location ($P = 0.07$). However, Jerseys were younger than Holsteins at first calving in all regions. The differences were significant in the Central ($P = 0.04$), Central south ($P < 0.01$) and Southeast regions ($P = 0.02$), all areas where heat-stress is more likely. In the analysis by states all the effects were highly significant ($P < 0.01$). Jerseys were younger at first calving than Holsteins in all states, except in Arizona, but the differences were only significant for the herds in Wisconsin ($P = 0.03$), California ($P = 0.03$), and Florida ($P = 0.02$). Table 1.5 shows that Jerseys were younger than Holsteins for all birth seasons in regions and states. Differences between breeds were significant ($P < 0.01$) for cows born in summer (regional data) or born in summer and fall (state data).

First calving interval. For the analysis by regions, all the effects were highly significant ($P < 0.01$). Jerseys had shorter FCI than Holsteins in all the breed comparisons in this study (Tables 1.6 and 1.7). Table 1.6 shows that the differences between Holsteins and Jerseys were largest in the Central south (35 d) and Southeast (26 d), when Holsteins increased FCI more than Jerseys. First calving interval was longest for both breeds in Central south. For the analysis by states, the effects of breed, geographic location, and first calving season were highly significant ($P < 0.01$), as well as the interaction of breed by first calving season ($P = 0.02$). Only the interaction of breed by geographic location was not significant ($P = 0.12$). However, differences between Holsteins and Jerseys were significant for California, Florida, and Texas ($P < 0.01$), and approached significance ($P = 0.06$) for Arizona (Table 1.6). These four states are more likely to produce heat-stress in cows at some point than the other three states. Jerseys had significantly shorter FCI than

Holsteins for all first calving seasons in the analysis by regions, and for spring, summer and winter in the analysis by states (Table 1.7).

Holsteins Housed with Brown Swiss and Holsteins Housed with Jerseys

We merged data from individual states from Holsteins housed with Brown Swiss and Holsteins housed with Jerseys to see if Holsteins performed similarly when managed with different breeds. For AFC, the effect of "type of Holstein" and the interaction of "type of Holstein" with birth season were highly significant (P <0.01). Holsteins housed with Brown Swiss calved for the first time at older ages than Holsteins housed with Jerseys (800 ± 2.7 d vs. 780 ± 2.5 d, respectively). Table 1.8 shows that maximum differences were in Arizona (46 d) and minimum in Texas (2 d).

Holsteins housed with Jerseys usually had about a week shorter FCI than Holsteins with Brown Swiss, but the differences between "types of Holstein" were not significant. The interaction of "type of Holstein" with first calving season was highly significant (P <0.01). The interaction occurred because Holsteins with Brown Swiss had shorter FCI for the herds in Florida (2 d) and Wisconsin (14 d) than Holsteins with Jerseys.

DISCUSSION

Fox and Tylutki (1998) predicted increased AFC in environments with heat-stress. Our study showed variable results for the Southern regions. These differences were probably due to the size of the dairy herds, different management systems, and to true breed differences. Jerseys can reach the minimum required weight for insemination at younger ages than other breeds (Badinga et al., 1985; Graves, 2003; Ruvuna et al., 1986). We observed this result mainly in the Southern regions, suggesting heat-stress resistance for Jerseys with respect to Holsteins. Jerseys were significantly younger than Holsteins at first calving when they were born in spring, summer and fall, again suggesting heat-stress resistance for Jerseys.

We also observed evidence of heat-stress resistance for Jerseys compared to Holsteins for FCI, as the difference between breeds was greater in the southern areas of the country. Our results agree with VanRaden et al. (2003), who found that Jerseys had higher pregnancy rates than Holsteins or Brown Swiss. Our results are also in accordance with Ruvuna et al. (1983), who reported longer days open for Holsteins than for Brown Swiss or Jerseys or their crosses, particularly in the warm season. Badinga et al. (1985) compared Holsteins, Brown Swiss and Jerseys and found higher conception rates and fewer services per conception for Jerseys in Florida. Campos et al. (1994) also reported better fertility for Jerseys than Holsteins in Florida.

Correa-Calderon et al. (2003) concluded that Brown Swiss showed evidence of heat-stress resistance when compared to Holsteins. In our results, Brown Swiss were older at first calving than Holsteins, regardless of region or season. This may be for a reason other than lack of heat-stress resistance. Pirlo et al. (2000) reported average AFC of 995 days from 1972 to 1995 for Brown Swiss in Italy, which is much higher than in the present study. Older AFC for Brown Swiss could be due to rate of maturity, independent of heat-stress resistance. Perhaps the genetic capability of Brown Swiss and management decisions could be confounded, as Brown Swiss have been reported to grow as fast as Holsteins (Ruvuna et al., 1986). Management effects must be important for AFC, because differences between Holstein and Brown Swiss were maximum in California (42 d) and minimum in Arizona (12 d). Brown Swiss had shorter FCI than Holsteins in the regions most likely to produce heat-stress, but the differences were not significant. Possibly the small numbers of Brown Swiss reduced our ability to detect significant differences.

The Southwest included the largest number of cows of all regions for both Holstein and Jersey or Holstein and Brown Swiss herds. For Southwest, AFC and FCI for both pairs of breeds were similar to northern regions, suggesting effective implementation of heat abatement procedures. Ray et al. (1992) reported that management practices had improved in Arizona. This state had the lowest AFC and FCI in both types of farms. Cooling techniques that involve sprinklers and fans are more effective in dry than humid conditions and could be successfully used in Arizona.

Fertility is curtailed under heat-stress (Jonsson et al., 1997; Kadzere et al., 2002) and insemination dates are influenced by calving dates. In frequency analyses not shown, we found that most first calvings occurred during fall, followed by spring or winter, depending on region. Apparently the season to avoid for calvings was summer, especially for the southern regions. VanRaden et al. (2003), in a study of regional effects on days open in Holsteins, showed that days open fluctuate more in the Southeast than the other regions by calving month. Thus for some months, days open in the Southeast is lower than in any other region. This result indicates beneficial effects of voluntary management of days open (Oseni et al., 2003), and as a consequence, of calving interval. Larger standard errors in regions or states most likely to produce heat-stress were partly due to relatively low numbers of cows and to seasonality of first calving seasons, and thus, of insemination seasons.

Both types of farms (HB and HJ) were in each of the individual states analyzed. Thus, the differential behavior of Holsteins when paired with Brown Swiss or Jerseys was not the result of unequal distribution of the two types of farms throughout the country, but from homogenizing management decisions. Holsteins behaved like the breed with which they were paired, even when FCI was not significantly different between Holsteins from the two types of farms.

This study is concerned with breed differences for AFC and FCI, regardless of production level, pedigree quality, or the influence of other traits. Our purpose was to compare the behavior of two breeds per dataset when they were subject to similar management decisions, under similar environmental conditions. Farms with relatively large number of cows of two breeds are rare in this country, but they are useful to study breed differences in routine management conditions.

CONCLUSION

Jerseys and, to a lesser extent, Brown Swiss showed evidence of heat-stress resistance in reproductive performance, relative to Holsteins. Longer calving intervals and older ages at first calving are not likely due entirely to effects of heat-stress on fertility, but also to intentional voluntary waiting period to breed heifers or rebreed cows. There was indirect evidence of heat abatement practices in some states. Such practices can help control AFC and FCI, especially in regions with low humidity.

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Table 1.1 Number of cows and herds in the Holstein-Brown Swiss datasets for the analyses by regions and states.

Regions	Cows		Number	States	Cows		Number
	Holstein	Brown Swiss	of herds		Holstein	Brown Swiss	of herds
Northwest	467	141	8	Ohio	131	75	5
Central north	867	520	47	Wisconsin	234	211	18
Northeast	490	191	33	Oregon	344	109	3
Central	544	261	28	California	904	174	8
Central south	298	291	8	Arizona	2068	347	4
Southeast	152	67	10	Texas	282	285	6
Southwest	3335	649	16	Florida	98	31	2

Table 1.2 Number of cows and herds in the Holstein-Jersey datasets for the analyses by regions and states.

Regions	Cows		Number	States	Cows		Number
	Holstein	Jersey	of herds		Holstein	Jersey	of herds
Northwest	1384	370	19	Ohio	123	96	6
Central north	501	334	29	Wisconsin	161	86	12
Northeast	1181	546	59	Oregon	416	231	13
Central	964	517	32	California	4513	2095	34
Central south	312	243	14	Arizona	713	1829	2
Southeast	955	585	22	Texas	209	129	10
Southwest	5518	4082	44	Florida	435	204	4

Table 1.3 Least squares means (SE) of age at first calving for breed by geographic location in Holstein-Brown Swiss herds in seven regions and seven states.

Regions	Holsteins	Brown Swiss	P[1]	States	Holsteins	Brown Swiss	P
Northwest	795 (5.0)	809 (7.1)	0.75	Ohio	791 (9.9)	829 (10.8)	<0.01
Central north	803 (3.3)	838 (3.6)	<0.01	Wisconsin	800 (5.2)	822 (13.0)	<0.01
Northeast	802 (4.3)	832 (5.3)	<0.01	Oregon	815 (4.6)	831 (7.1)	0.65
Central	801 (4.2)	847 (4.8)	<0.01	California	820 (4.3)	862 (5.9)	<0.01
Central south	809 (5.7)	835 (6.5)	<0.01	Arizona	780 (1.8)	792 (3.6)	0.19
Southeast	819 (7.6)	834 (9.2)	0.96	Texas	811 (4.9)	836 (5.7)	<0.01
Southwest	812 (2.7)	833 (3.6)	<0.01	Florida	801 (8.2)	822 (13)	0.96

[1] P = *P*-values defining the significance of difference between least squares means of breed, by region or state, using Tukey-Kramer tests.

Table 1.4 Least squares means (SE) of age at first calving for breed by birth season in Holstein-Brown Swiss herds in seven regions and seven states.

	In regions				In states		
Birthseason	Holsteins	Brown Swiss	P[1]	Birthseason	Holsteins	Brown Swiss	P
Spring	805 (2.7)	829 (3.6)	<0.01	Spring	806 (3.2)	824 (4.5)	<0.01
Summer	807 (2.6)	829 (3.4)	<0.01	Summer	801 (3.1)	825 (4.3)	<0.01
Fall	802 (2.4)	838 (3.4)	<0.01	Fall	796 (2.9)	839 (4.4)	<0.01
Winter	811 (2.5)	835 (3.7)	<0.01	Winter	810 (2.9)	835 (4.5)	<0.01

[1] P = *P*-values defining the significance of difference between least squares means of breed, by birth season in regions or states, using Tukey-Kramer tests.

Table 1.5 Least squares means (SE) of age at first calving for breed by birth season in Holstein-Jersey herds in seven regions and seven states.

	In regions				In states		
Birth season	Holsteins	Jerseys	P[1]	Birth season	Holsteins	Jerseys	P
Spring	814 (2.0)	806 (2.3)	0.07	Spring	782 (2.8)	781 (3.1)	0.99
Summer	812 (1.9)	797 (2.2)	<0.01	Summer	788 (2.9)	775 (3.1)	<0.01
Fall	803 (1.8)	797 (2.1)	0.23	Fall	784 (2.8)	772 (3.1)	<0.01
Winter	811 (1.9)	809 (2.8)	0.45	Winter	787 (2.8)	784 (3.1)	0.98

[1] P = *P*-values defining the significance of difference between least squares means of breed, by birth season in regions or states, using Tukey-Kramer tests.

Table 1.6 Least squares means (SE) of first calving interval for breed by geographic location in Holstein-Jersey herds in seven regions and seven states.

Regions	Holsteins	Jerseys	P[1]	States	Holsteins	Jerseys	P
Northwest	414 (4.7)	400 (5.1)	0.15	Ohio	421 (9.0)	405 (9.6)	0.95
Central north	414 (4.7)	390 (5.1)	<0.01	Wisconsin	394 (7.7)	383 (8.5)	0.99
Northeast	409 (3.4)	399 (3.8)	0.71	Oregon	407 (5.7)	404 (6.2)	0.99
Central	423 (3.7)	402 (4.1)	<0.01	California	403 (2.6)	395 (2.9)	0.01
Central south	461 (4.9)	426 (5.6)	<0.01	Arizona	401 (9.1)	390 (9.1)	0.06
Southeast	439 (3.9)	413 (4.3)	<0.01	Texas	461 (5.8)	432 (7.1)	<0.01
Southwest	408 (2.3)	397 (2.5)	<0.01	Florida	446 (4.2)	424 (5.6)	<0.01

[1] P = *P*-values defining the significance of difference between least squares means of breed, by region or state, using Tukey-Kramer tests.

Table 1.7 Least squares means (SE) of first calving interval for breed by first calving season in Holstein-Jersey herds in seven regions and seven states.

First calving season	In regions Holsteins	Jerseys	P[1]	First calving season	In states Holsteins	Jerseys	P
Spring	424 (2.0)	401 (2.3)	<0.01	Spring	418 (2.9)	397 (3.1)	<0.01
Summer	421 (2.5)	402 (2.7)	<0.01	Summer	417 (3.3)	402 (3.5)	<0.01
Fall	424 (1.9)	410 (2.2)	<0.01	Fall	423 (3.0)	415 (3.5)	0.45
Winter	427 (2.2)	402 (2.6)	<0.01	Winter	417 (3.0)	404 (3.4)	0.01

[1] P = *P*-values defining the significance of difference between least squares means of breed, by first calving season in regions or states, using Tukey-Kramer tests.

Table 1.8 Least squares means (SE) of age at first calving for Holsteins housed with Brown Swiss or with Jerseys in seven states.

	HB Holsteins[1]	HJ Holsteins[2]	P[3]
Ohio	775 (11.9)	759 (8.9)	0.99
Wisconsin	802 (6.0)	775 (1.3)	0.16
Oregon	815 (4.8)	808 (5.7)	0.99
California	818 (5.4)	801 (3.1)	0.08
Arizona	780 (1.8)	734 (8.4)	<0.01
Texas	806 (5.6)	804 (5.3)	0.99
Florida	801 (8.2)	776 (3.5)	0.26

[1] HB Holsteins = Holstein housed with Brown Swiss.

[2] HJ Holsteins = Holstein housed with Jerseys.

[3] P = *P*-values defining the significance of difference between least squares means of type of Holstein, by state, using Tukey-Kramer tests.

CHAPTER IV

Manuscript 2

Breed, region, and breed by region interaction effects in Brown Swiss, Holsteins and Jersey cows for measures of true longevity up to five years of age

ABSTRACT

The objectives of this study were to compare survival-related traits, and to assess the breed by region interactions for three breeds in seven regions of the United States. The traits were stayability, number of completed lactations, days lived, herd-life, and total days in milk up to five years of age in Holstein, Brown, and Jersey cows. There were three datasets: herds with one breed of cows, herds with Holsteins and Brown Swiss, and herds with Holsteins and Jerseys. For herds with one breed of cows, the order, from longer to shorter-lived breed for stayability was: Brown Swiss, Jersey and Holstein, but for the rate of days in milk over herd-life the order was: Holstein, Jersey and Brown Swiss, and for the ratio of days in milk to days lived, it was: Jersey, and Holstein and Brown Swiss tied. This order held for number of lactations completed by five years of age. The results for herds with two breeds of cows were similar since Brown Swiss and Jerseys had larger (Chi-square $P < 0.01$) probabilities than Holsteins of living past five years of age. For days in milk, and number of lactations completed, Jerseys had higher values than Holsteins ($P < 0.01$). Holsteins and Brown Swiss tied in most analyses of days in milk and number of LAC5. Breed by region interaction was usually significant. Jerseys started their productive life younger than the other two breeds and subsequently calved more frequently.

(**Key words:** breed comparison, regions, survival)

Abbreviation key: DL5 = number of days lived up to five years of age, **HB** = farms with Holsteins and Brown Swiss, **HJ** = farms with Holsteins and Jerseys, **HL5** = herd-life up to five years of age, **LAC5** = Number of lactations completed by five years of age, **DIM5** = days in lactation up to five years of age.

INTRODUCTION

Dairy breeds are well defined for conformation and production, but further study is justifiable for fitness traits, such as longevity. Longevity has the highest impact on herd profitability after milk production (VanArendonk, 1991; Jagannatha, et al. 1998). Longer longevity reduces the cost of replacing cows, increases the proportion of cows in the higher producing age groups, and allows higher rates of voluntary culling. Voluntary culling is practiced in part to accelerate milk production genetic progress. However, genetic progress is mainly attained by the use of superior sires of replacement heifers. A faster turnover of cows has small genetic improvement consequences intra-herd (Allaire, 1981).

Longevity is usually evaluated through related traits. Longevity traits can be binary (usually called stayabilities: yes/no lived up to a specified point), countable (lactations, years), or continuous (days, months). Stayabilities and number of lactations are categorical traits, and can be evaluated using Logistic and Poisson regressions, respectively (Agresti, 2002; Stokes, et al., 2000). Longevity is measured as “Productive Life” in the United States, Productive Life is defined as the total months of milk production, limited to 10 mo per lactation, and up to seven years of age of the cow (VanRaden and Klaasgate, 1993). Life, so defined, is unadjusted for milk produced. This type of longevity measurement is called true longevity, as opposed to functional longevity that adjusts length of life by production. Vollema and Groen (1996) found that heritability estimates of functional longevity were lower than those of true or uncorrected longevity. Different definitions of longevity, such as number of lactations completed, and/or stayability to different periods are used internationally. Some countries adjust for milk production and/or include conformation traits. Still the genetic and phenotypic correlations between the evaluations range from moderate to high (60-90%) (Van der Linde and De Jong, 2002; VanRaden and Powell, 2002). Dairy cow longevity is not homogeneous throughout the United States (Caraviello, et al., 2004), but breed by region interactions for longevity-related traits in dairy cows has not been studied.

Five years constitutes the average lifetime of dairy cows, since the typical number of lactations per cow in the United States is 2.8 (calculated from Productive Life evaluations, USDA, AIPL website, assuming average lactations of 305 d). In a Canadian study of most profitable replacement strategy for Alberta dairies, replacing cows at the end of their sixth lactation resulted in the highest annuity value, but differences were minor from the third to the tenth lactation. Replacements at the end of the third lactation resulted in annuity values only about 3% less than the maximum. Loss of profit was very significant when cows lasted only one or two lactations (Mason, 2004). By studying the first five years of life of cows, we emphasize speed of returns to rearing costs, and the advantages of early calving and short calving intervals,

Weigel, et al. (2003) found evidence for Wisconsin, that increasing numbers of high producing cows had been leaving herds in expansion before lower producing cows. Such involuntary culling suggests that higher levels of milk yield are related to reduced longevity. New generations of dairy cows are constantly increasing production of milk and milk-components. At the same time, fertility-related traits tend to deteriorate (UDSA AIPL). Furthermore, intra-herd reasons for disposal also change through time (Westell, et al., 1982). By studying outcomes from cow populations with only a few birth-years range, we have a sample from a more homogeneous population,

The present study evaluated the performance, during five years of life opportunity, of cows born from January 1992 to June 1996 for survival-related traits. We used Holstein, Brown Swiss and Jersey herds, and herds with two breeds of cows: Holstein and Brown Swiss or Holstein and Jersey. Herds with one breed of cows are more numerous, and perhaps more representative of the dairy industry in the United States, while herds with two breeds of cows offer a better comparison of the breeds involved since management decisions and breed performance are influenced by a common environment.

The objectives of this study were to compare the three most abundant breeds of dairy cows in the United States for the survival-related traits stayability, number of completed lactations, days lived, herd-life, and days in milk up to five years of age (1825 d), and to assess breed by region interactions for seven regions of the United States.

MATERIALS AND METHODS

Data were provided by the Animal Improvement Program Laboratory, USDA, and included individual cow test day records from all Jersey and Brown Swiss in the United States, and test day records on all Holstein cows in herds with the same zip code as Brown Swiss or Jersey cows. The country was divided into seven regions: Northeast, North central, Northwest, Central, Southeast, South central, and Southwest. The states in each region are shown in Table 2.1. The herds included reported lactation records from calvings every year from January, 1995 to June 2001. All cows in the study were in the same herd throughout five years of life opportunity (1825 d), or until culling. At the end of the five years opportunity, data on individual cows were truncated. Maximum age at first calving allowed was three years (1095 d). Three datasets were analyzed: herds with single breeds of Brown Swiss, Holstein, and Jersey; herds with both Holsteins and Brown Swiss (**HB**), and herds with both Holsteins and Jerseys (**HJ**). For these datasets, raw means for the traits analyzed, plus age at first calving, are shown in Table 2.2. The dataset of herds with one breed included 15,165 cows in 1308 Brown Swiss farms, 1,793,952 cows in 27,906 Holstein farms, and 104,217 cows in 3,309 Jersey farms. The datasets of herds with two breeds included 26,469 Holstein and 4,697 Brown Swiss cows in 223 HB farms, and 23,937 Holstein and 6,791 Jersey cows in 250 HJ farms. The number of cows per dataset and region are shown in Table 2.3.

For the three datasets, stayability (yes/no survived), number of completed lactations (**LAC5**), days lived (**DL5**), herd-life (**HL5**), and days in milk (**DIM5**) up to five years of age (1825 d), were analyzed. Herd-life was calculated as DL5 minus age at first calving. Days in milk (days in lactation) consisted of HL5 minus dry periods. The number of lactations up to five years of age consisted of completed lactations. Lactations in progress at five years of age were not counted. Survival up to or beyond five years of age and LAC5 were analyzed with the GENMOD procedure of SAS® with the CONTRAST statement used to test significant differences between specific pairs of variables.

Days lived, HL5, and DIM5 were analyzed with the MIXED procedure of SAS® (Littell, et al., 1996). Days in milk was also analyzed with Survival Analysis (Ducrocq and Solkner, 2000).

Likelihood ratio tests were used to test significance of breed by region interaction for the stayability, LAC5, and Survival analyses. If the interaction was significant, another analysis was conducted including the interaction, but without the effects of breed and region.

Several cow predicted transmitting ability values (cPTA) were provided by AIPL, USDA. Correlations among c**PTA** values were obtained (Table 2.4). cPTA milk and cPTA protein were highly correlated, and cPTA protein was not used. Three classes for cPTA milk, somatic cell score, and productive life were obtained by adding and subtracting half the standard deviation to the average cPTA value (per breed, per dataset); the cows inside this range were class 2. Class 1 included all the cows that were below that range; and class 3 all those cows with larger values. We verified that similar numbers of cows per dataset were in each class. cPTA classes were fitted in the survival analysis of DIM5 for herds with two breeds of cows.

The models used were:

i) For stayability at five years of age:

Y_i = 1 if alive (with probability Π), or 0 if dead (with probability 1-Π), at five years of age, with a relationship between Π_i and covariates x_i of the same cow described by:

$$\ln[\, \Pi_i \;/\; 1-\Pi_i \,] = \mathbf{X}'\beta$$

where: X = incidence matrix with a column of 1's (for the intercept, β_o) and 1's indicating birth year-birth season group, breed, region, and breed by region interactions (xi), otherwise 0

β = vector of parameters; parameters other than β_o indicate an increment of the logit per change in xi

$\ln[\, \Pi_i \;/\; 1-\Pi_i \,]$ = log of the odds or logit

$\Pi_i \;/\; 1-\Pi_i$ = odds

ii) For LAC5:

$$\ln(Y_i) = \mathbf{X}'\beta$$

where: Y = LAC5, assumed following a Poisson distribution,

X as before

β = parameter indicating the change in the log of the expected group mean per change in x_i

iii) For DL5, HL5, and DIM5:

$$Y = \mathbf{X}'\beta + \varepsilon_{ijkl}$$

where: Y = DL5, HL5, or DIM5,

X = incidence matrix with a column of 1's (for μ) and 1's indicating the covariates (xi): birth year-birth season of the cow, breed, region, and breed by region interaction (for herds with two breeds, herd nested in region was added), otherwise 0,

β = vector of solution parameters

ε = residual, assumed ~ N (0, $I\sigma^2$).

iv) For DIM5:

$$\lambda(t; x) = \lambda_0(t) \exp(X'\beta)$$

where: $\lambda(t; x)$ = proportional hazard (or instantaneous rate) of stopping accumulating days in lactation due to death or removal, influenced by the effects of factors xi,

$\lambda_0(t)$ = baseline hazard following a Weibull distribution,

X as in equation iii) for herds with one and two breeds, but adding cPTA classes for herds with two breeds

β vector of parameters representing the relative risk of stopping accumulating days in lactation due to death or removal.

Probabilities of survival (yes/no) to five years of age were calculated as:

Π_i = EXP (parameter estimate)/(1 + EXP(parameter estimate)

The expected number of lactations completed at five years of age was calculated as:

$$E\ (LAC5_i) = EXP\ (intercept + parameter\ estimate)$$

RESULTS

Table 2.3 shows that for the herds with one breed of cows, more than 80% of Brown Swiss and Holstein cows were in three regions: North central, Southwest, and Northwest for Brown Swiss, and North central, Southwest, and Central for Holsteins. Jerseys were more evenly distributed, as well as cows in the herds with two breeds of cows. There were relatively few Brown Swiss and Jersey cows in Northwest for herds with two breeds, and for that region there were no main breed effect differences for any trait.

The overall statistical differences of breed, region and their interaction effects will be mentioned at the beginning of each section. Tables 2.5 and 2.6 contain the statistical differences for breed by region interactions for stayability and LAC5, respectively. Tables 2.7 and 2.8 contain the least squares means for DL5, HL5, and DIM5 in herds with one breed of cows, with the corresponding statistical differences in Table 2.9. There are no Tables for herds with two breeds for DL5, HL5, and DIM5, but the least squares means and the levels of significance will be mentioned when appropriate.

In general, results for herds with one breed appear first, followed by results for the herds with two breeds.

Analyses using Categorical Methods

Figures show the probability of the cows to be alive at five years of age for stayability in the Logistic analyses, or the expected number of lactations for the Poisson analyses. For the logistic analysis, the reference group has 50 percent probability of survival (and 50 percent probability of not survival) to five years of age, which represents lack of information, and for the Poisson analysis, the reference group has the overall expected number of lactations from the analysis. Corresponding confidence interval tables were added to each Figure in this section as reference.

Stayability. In herds with one breed of cows, logistic analysis showed overall significant differences for breed, region and breed by region interaction effects (Chi-square $P < 0.01$). Breed contrasts showed that Holsteins had consistently lower survival than Brown Swiss and Jerseys (Chi-square $P < 0.01$ with respect to both Brown Swiss and Jerseys). Brown Swiss and Jerseys differences approached significance (Chi-square $P = 0.08$).

Figure 1 and Table 2.5 present the probabilities obtained for breed by region interaction, showing that Jerseys tended to live longer than Brown Swiss in the Central region (Chi-square $P < 0.01$), while Brown Swiss lived longer than Jerseys in North central (Chi-square $P < 0.01$) and South central (Chi-square $P = 0.04$).

In herds with two breeds of cows, Jerseys lived significantly longer than their Holstein herd-mates (Chi-square $P < 0.01$ for breed effect), while Brown Swiss and Holstein cows housed together were not significantly different (Chi-square $P = 0.54$). However, the overall breed by region interaction was highly significant (Chi-square $P < 0.01$) in both types of farms. Figure 2.2 shows how Brown Swiss outlived (Chi-square $P < 0.01$) Holsteins in Northeast, Central, and Southeast. In HJ herds (Figure 2.3), Jerseys outlived Holsteins in all regions (Chi-square P <

0.01, except in Northwest), but Figure 2.3 shows larger differences in South central, Southeast and Southwest. Specific breed by region significance differences are listed in Table 2.5.

Number of Lactations completed by five years of age. In herds with one breed of cows, Poisson analysis showed overall highly significant differences (Chi-square $P < 0.01$) for breed, region, and their interaction. Only Northeast and Central had positive parameter estimates with respect to Southwest for overall region effect. Table 2.6 and Figure 2.4 present results for the breed by region interaction. Brown Swiss and Holsteins had negative estimates with respect to Jerseys. Jerseys were likely to have more lactations in Central region, whereas Brown Swiss and Holsteins were likely to have least number of lactations in Southeast. Brown Swiss and Holsteins were not significantly different in Northeast, Northwest, Central South and Southeast (Table 2.6).

In herds with two breeds, breed and the interaction of breed by region were not significant in HB farms. In HJ farms, Jerseys' parameters were significantly more lactations than Holsteins, especially in Southeast, South central, and Southwest (Table 2.6 and Figure 2.5).

Analyses using linear models

In herds with one breed, the overall effects of breed, region, and breed by region interaction were highly significant ($P < 0.01$) for DL5, HL5, and DIM5. Tukey statistical differences for breed by region interaction are listed in Table 2.9.

No Table is presented for herds with two breeds of cows, since differences were few. However, the overall breed by region effect was significant ($P < 0.01$) for DL5, HL5, and DIM5.

Days lived up to five years of age. For herds with one breed, breed least squares means were about a month (29 d) less for Holsteins than either Brown Swiss or Jerseys, which were not significantly different (P = 0.98). Table 2.7 presents the breed by region least squares means and Table 2.9 the statistical differences. Breed performance was very similar in the Southwest.

In HJ farms, breed and breed by region interaction effects were significant, and Jerseys always lived longer (P < 0.01 for breed main effect) than their Holstein herd-mates (not depicted). For breed by region interaction, the differences were marginally significant in Northeast (P = 0.07) and North central (P = 0.08), and there were no significant differences in Northwest. In HB farms there was no overall breed difference (P = 0.33); however, for the breed by region interaction effect, Brown Swiss lived more days than Holsteins (P < 0.01) in Central (1583 ± 12.2 d vs. 1540 ± 8.9 d), Southeast (1657 ± 22.1 d vs. 1573 ± 12.6 d), and North central (1574 ± 9.9 d vs. 1542 ± 7.9 d), with no significant differences for the other regions.

Herd-Life up to five years of age. In herds with one breed of cows, Jerseys had the longest herd-life in all regions (Table 2.7). Brown Swiss were not significantly different from Holsteins in most regions for HL5, contrasting with the results from the DL5 analysis, when Brown Swiss lived more days in their five years of life opportunity than Holsteins. Since the difference between DL5 and HL5 is age at first calving, it is clear that Brown Swiss lost its advantage over Holsteins due to older ages at first calving.

However, in herds with two breeds, Brown Swiss' shorter HL5 (18 d) was only marginally different than Holsteins' (P = 0.09 for breed main effect), and the breed by region interaction was significant only in Southwest (700 ± 14.7 d for Brown Swiss vs. 748 ± 8.2 d for Holsteins).

In HJ farms Jerseys had longer HL5 than Holsteins, but the differences were significant only in Central (P = 0.05 with 42 d difference) and Southeast (P < 0.01 with 83 d difference).

Days in milk up to five years of age. In herds with one breed of cows, Brown Swiss and Holsteins were not significantly different in Northwest, Southeast, and South central, and Holsteins and Jerseys were not significantly different in North central (Table 2.8). In general, Jerseys had the most DIM5 and Brown Swiss had the least (Table 2.9). There were larger differences between Jerseys and Holsteins in Central, Southeast, and South central regions (78, 73, and 52 d, respectively), regions where heat stress is most likely.

In HB herds, Holsteins usually had more DIM5 than Brown Swiss (except in Southeast, where Brown Swiss had 48 d more DIM5 than Holsteins), while in HJ herds, Holsteins usually had less DIM5 than Jerseys (except in Northeast where Holsteins had 15 d more DIM5 than Jerseys). There were few significant differences, though; only in Northeast (P = 0.03 with 635 ± 5.8 d for Holsteins vs. 591 ± 11.1 d for Brown Swiss) and Southwest (P < 0.01 with 610 ± 5.6 d for Holsteins vs. 561 ± 11.7 d for Brown Swiss) for HB farms, and in Southeast (P < 0.01 with 656 ± 10.4 d for Jerseys vs. 587 ± 6.5 d for Holsteins) for HJ farms.

Days in milk/ herd-life and days in milk/ days lived. Percentages of DIM5 per HL5 and DIM5 per DL5 give a clearer comparison of the behavior of the three breeds across regions.

In herds with one breed of cows, Holsteins spent more time lactating during their HL5 than Brown Swiss or Jerseys (Figure 2.6). However, the ratio of DIM5 to DL5 (Figure 2.7) shows that Jerseys had the highest percentage of DIM5 by age in the three datasets, followed by Holsteins. Similar trends were found for herds with two breeds of cows (Figure 2.8).

Analysis of Days in milk using Survival Analysis

Herds with one breed of cows. Breed**,** region, breed by region interaction, and birth year-birth season were highly significant (Chi-square $P < 0.01$). The ρ parameter was 1.36 when the full model or the model without main effects was run. Thirty-nine percent of the records were right censored, with an average censoring time of 837 DIM5, out of a maximum time of 1214 DIM5. Uncensored records had an average failure time of 439 DIM5, out of a maximum of 1201 DIM5.

The region with largest DIM5 average was Southwest with 619 d, and the region with the lowest DIM5 average was North central with 567 d. The DIM5 averages for the breeds were: 554 d for Brown Swiss, 592 d for Holsteins, and 633 for Jerseys. Risk ratios per breed by region are depicted in Figure 2.9. Lower values mean lower risk (or longer DIM5 attained, in this case); i.e. Brown Swiss in Northeast had a risk of 1.1, meaning their risk is to have 10% less DIM5 than the reference. Jerseys in Southwest were set as reference. Holsteins and Brown Swiss almost always had higher risks than Jerseys, except that Brown Swiss tied with Jerseys in South central and the three breeds practically had the same risks in North central. These results are in general agreement with the linear model analysis performed for DIM5 (Table 2.9). Brown Swiss' DIM5 were fewest in the Central (where Brown Swiss had the highest risk), and most in the South central (where Brown Swiss had their lowest risk), while Jerseys had more DIM5 than the other breeds, and accordingly, their risk was the least for all regions (Table 2.9 and Figure 2.9). However, Holsteins' risks were larger than Brown Swiss' in Northeast, Northwest, Central south, and Southeast (Figure 2.9), and Table 2.9 shows that Holsteins had more DIM5 than Brown Swiss is all regions, except South central. Besides, in North central, the three breeds had similar risks, but Table 2.9 shows that Brown Swiss had less DIM5 than

Holsteins and Jerseys. The Survival Analysis could detect that in those regions Brown Swiss had an advantage in stayability, and lived significantly longer than Holsteins (and longer than Jerseys in North central), as was shown in Figure 2.1. Thus, additional information used by Survival analysis resulted in Brown Swiss' improved risk levels for some regions.

Herds with two breeds of cows. For HB farms, the ρ parameter was 1.64 for the full model, the model without main effects, and for a preliminary analysis (full model) where we considered sire variance using relationships in a sire-maternal grandsire model. The significance of all estimates were unchanged whether considering the sire variance (in the preliminary analysis) or not. Breed effect was not significant (Chi-square $P = 0.45$), but the interaction of breed by region was (Chi-square $P < 0.01$), as well as region, and the cPTA classes for milk, productive life, and somatic cell score.

For HJ farms, the ρ parameter was 1.69 for both the full and the model without main effects. Breed, region, breed by region and the cPTA classes for milk and productive life were highly significant (Chi-square $P < 0.01$), but not the cPTA class for somatic cell score (Chi-square $P = 0.14$).

Jerseys had 26 % lower risk (more DIM5) than Holsteins. The risk ratios for HB farms, by region, are depicted in Figure 2.10, from where it is clear that Brown Swiss had highest risks in Northeast (where Brown Swiss had significantly less DIM5 than Holsteins), and lowest in Southeast (where Brown Swiss had the highest stayability for HB farms). The risk ratios for both types of farms for the cPTA classes are presented in Table 2.10. The higher the cPTA class for milk or for productive life, the lower the risk (or the more DIM5, in this case). The results for somatic cell scores are contradictory for HB farms, in the sense that both the lower and higher classes have lower risks than the intermediate class. Probably this is the result of somatic cell scores being directly related to amount of milk production, with a genetic correlation of 0.2 (VanRaden and Seykora, 2003), even though for our data, the phenotypic correlation between milk and somatic cell score cPTA's was low (Table 2.4).

DISCUSSION

Dairy breeds can be compared for lifetime productive life by looking at the national evaluations (USDA, AIPL website). Lifetime production and longevity traits (age at culling, length of productive life, and number of lactations completed) are positively correlated (Hoque and Hodges, 1981). For all evaluations, since 1960 to the current November 2004, Jerseys had longer productive lives than Brown Swiss or Holsteins. In this study, the time allowed to each individual to express the different longevity-related traits studied, was set to five years. Genetic and phenotypic correlations of stayabilities (yes/no survived) to different ages are moderate to high, often above 70% (Hudson and Van Vleck, 1981). If this is the case, the stayability used, to five years of age, should be an indicator of total survival. By using stayability or DL5 as longevity measurement, we would conclude that both Brown Swiss and Jerseys have similar longevities up to five years of age, both living longer than Holsteins. Raising replacement heifers is the second largest expense on a dairy operation (after feeding costs for the milking herd), representing approximately 20% of the budget (Heinrichs, 1993; Lissow, 1999). In this respect, Jerseys and even Brown Swiss (without fast returns), had an advantage over Holsteins. Vollema and Groen (1996), using numerous longevity-related traits, found that longevity decreased when the proportion of Holstein genes increased in their Dutch Friesian populations in The Netherlands. This is in agreement to our findings that Holsteins tend to live less than the other two breeds compared in this study.

For the ratio DIM5/HL5, Brown Swiss often had lowest values. Since the difference between HL5 and DIM5 is the dry period, Brown Swiss would be the least profitable cow, according to Van Horn and Wilcox (1992), because a low profit cow is determined by the length of the non-productive dry period. The lactating cows must provide income for themselves as well as the dry cows. Nevertheless, a very high ratio of DIM5 over HL5 might also mean that the cow has reproductive problems since she has extended lactations. The number of lactations completed aids in determining if reproductive limitations exist. Jerseys performed best for number of lactations completed.

Foster (1988), with simulated data, found the mean time from birth to payoff for an average cow was 60 mo, with a 15 mo range, depending mainly on age at calving. In our study, Jerseys would be able to pay themselves off faster than Holsteins assuming equal amount of money invested per pound of milk produced. This is not unreasonable. Jerseys produce less milk than Holsteins, but are smaller, reducing maintenance costs. Jerseys could generate similar profits than Holsteins, despite lower yields. If that is not the case, and Holsteins have a significantly larger relative production, they could well have paid off by the time they on average leave the herd. A study of costs per pound of milk produced per breed would be useful to verify that assumption. Brown Swiss probably would need the largest amount of time for payoff, unless their maintenance costs were comparatively lower than other breeds.

Sires with higher genetic merit for lactation yields have daughters that survive longer, probably due to voluntary culling (Rogers et al., 1988), in clear agreement to our findings about milk cPTA classes. However, for PL cPTA's, larger PTA's were partly result of the cow's own longer Productive

Life (which is related to DIM5), probably causing an overestimation of the PL cPTA class effect.

By using number of completed lactations by five years of age, we excluded many cows that were still lactating. Days in milk could be considered censored data because some cows are still lactating when they become five years old or simply because they could accumulate more DIM5 if a larger opportunity would have been given. This type of censoring, when the time allowed per individual is pre-determined, can also be handled by the Survival Kit (Ducrocq and Solkner, 1999) for Survival Analysis. The Survival Kit was used to analyze DIM5, assuming the "failure rates" or times when cows stopped accumulating days in lactation can be modeled with the very flexible life distribution, Weibull. All the effects (called "covariates") were considered time-independent, thus the two main differences between Survival Analysis and the other analyses in this study were that cows still alive when they reached five years of age were considered censored, and the application of the Weibull distribution. Survival analysis models the time elapsed from one event to another. In this case, the time modeled is a composite of various sub-times, the lactations, which contribute to DIM5. In this study, the Survival analysis was trying to answer a slightly different question than the cow's behavior by 5 years of age, since the program estimates the probable total survival. Survival analysis could also have been used to analyze number of lactations completed in a grouped data analysis with a distribution similar to Weibull (Prentice and Gloeckler, 1978; Ducrocq and Solkner, 2000). For the three datasets, the ρ parameters were larger than 1, meaning that the risk increased with time.

We found that a long herd-life does not guarantee rapid profit. Probably Brown Swiss will be a very profitable breed, but not in the first five years of life. Brown Swiss have older ages at first calving that reduce the time lactating. Garcia-Peniche, et al. (accepted) found Holsteins to have longer calving intervals than Jerseys, but not different to Brown Swiss. Here, we also found indirect evidence that Jerseys have shortest calving intervals, since they had more lactations completed. Jersey's advantage in the five years studied is partly due to their younger ages at first calving. This advantage apparently is carried all through their lives, as the difference between Jerseys and Brown Swiss for complete evaluations of productive life is about three months (USDA, AIPL site, 2004), the age at first calving difference between the two breeds.

Several factors other than breed and region might affect longevity. One such factor is herd-size. However, fitting herd-size classes in the model did not modify the overall conclusions of this work about breed, region, and breed by region interaction effects (Appendix). The present study was concerned about regional effects and their interaction with breed, since for genetic evaluations region would be a stable factor, while herd-size changes constantly, sometimes drastically, for every farm.

CONCLUSION

In all the different analyses, Jerseys showed an advantage for all the longevity-related traits studied. Brown Swiss showed good longevity performance, but their old ages at first calving limit the speed of return when it is evaluated up to five years of age. Holsteins lived less than the other two breeds. Breed by region interaction was always present and probable heat-stress could have affected Holsteins.

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Table 2.1 States included in the seven regions of this study.

Northeast	Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Delaware, Maryland, Vermont, Rhode Island, New Jersey.
North central	Michigan, Wisconsin, Iowa, Minnesota, South Dakota, North Dakota.
Northwest	Idaho, Washington, Oregon, Montana, Wyoming.
Central	Ohio, Indiana, Illinois, Kansas, Nebraska, Missouri, Kentucky, Tennessee, Virginia, West Virginia.
Southeast	Florida, Georgia, South Carolina, North Carolina, Alabama, Mississippi, Arkansas, Puerto Rico.
South central	Texas, Oklahoma, Louisiana.
Southwest	Colorado, New Mexico, Arizona, Utah, California, Nevada.

Table 2.2 Raw means (SD) of the traits analyzed for the three datasets in this study.

	Herds with one breed			Herds with two breeds			
Trait	Brown Swiss	Holstein	Jersey	Holstein	Jersey	Brown Swiss	Holstein
AFC[1]	855 (98.5)	814 (95.7)	784 (97.5)	807 (100.3)	808 (97.4)	847 (96.9)	798 (87.8)
STAY[2]	0.42 (0.49)	0.38 (0.49)	0.45 (0.5)	0.42 (0.49)	0.51 (0.5)	0.47 (0.5)	0.43 (0.49)
LAC5[3]	2.04 (0.84)	2.12 (0.86)	2.33 (0.93)	2.18 (0.86)	2.4 (0.87)	2.15 (0.84)	2.22 (0.86)
DL5[4]	1509 (344.8)	1503 (341.2)	1528 (350.2)	1542 (323.6)	1587 (320)	1564 (323)	1547 (323.3)
HL5[5]	653 (343.5)	689 (342.6)	743 (355.4)	735 (324.7)	779 (323.1)	717 (326.4)	749 (327)
DIM5[6]	554 (280.2)	592 (280.3)	633 (290.7)	628 (267.2)	660 (269.7)	606 (267.4)	634 (266.5)

[1] AFC: Age at first calving; trait not included as an outcome in the analyses.

[2] STAY: Stayability or survival (yes/no) at five years of age.

[3] LAC5: Number of lactations completed by five years of age.

[4] DL5: Days lived up to five years of age.

[5] DIM5: Number of days in lactation at five years of age.

Table 2.3 Number of cows per region in the three datasets of this study.

	Herds with one breed of cows [1]			Herds with two breeds of cows [2]			
Region	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey	Holstein
Northeast	1026	87,201	11,534	722	4842	1603	7941
North central	6601	588,776	15,391	1602	4836	880	1641
Northwest	3762	176,123	17,867	37	1984	73	852
Central	923	397,466	25,408	930	3362	1080	3350
Southeast	464	49,109	8448	234	1053	883	3788
South central	343	35,744	6202	472	1399	312	1058
Southwest	2046	459,533	19,367	700	8993	1960	5307

[1] Dataset one.

[2] Datasets two and three: Holstein-Brown Swiss and Holstein-Jersey herds.

Table 2.4 Correlations among cow PTAs in the Holstein-Brown Swiss (above diagonal) and Holstein-Jersey (below diagonal) datasets.

	PTAmilk	PTApL	PTAscs	PTAprot
PTAmilk		0.26	0.01[1]	0.87
PTApL	0.27		-0.39	0.28
PTAscs	0.03	-0.33		0.02
PTAprot	0.85	0.31	0.03	

[1] Probability difference = 0.15. All other pair differences had *P*-values < 0.1.

Table 2.5 Chi-square probability differences between breeds for stayability in Brown Swiss (B), Holsteins (H) and Jerseys (J) in herds with one and two breeds of cows in seven regions of the United States.

	Herds with one breed of cows			Herds with two breeds of cows	
Region	B vs. H	B vs. J	H vs. J	B vs. H	J vs. H
Northeast	< 0.01	0.34	< 0.01	< 0.01	< 0.01
Central	0.16	< 0.01	< 0.01	< 0.01	0.01
North central	< 0.01	< 0.01	0.74	0.04	<0.01
Northwest	< 0.01	0.12	< 0.01	0.79	0.63
South central	< 0.01	0.04	< 0.01	0.10	< 0.01
Southeast	< 0.01	0.45	< 0.01	< 0.01	< 0.01
Southwest	0.22	0.08	< 0.01	0.60	< 0.01

Table 2.6 Chi-square probability differences between breeds for number of lactations completed by five years of age in Brown Swiss (B), Holsteins (H), and Jerseys (J) in herds with one breed of cows and in herds with Holstein and Jersey cows in seven regions.

	Herds with one breed of cows			Herds with two breeds of cows [1]
Region	B vs. H	J vs. H	B vs.J	H vs. J
Northeast	0.5914	< 0.01	< 0.01	0.0175
Central	< 0.01	< 0.01	< 0.01	< 0.01
North central	< 0.01	< 0.01	< 0.01	0.0177
Northwest	0.2941	< 0.01	< 0.01	0.4363
South central	0.9773	< 0.01	< 0.01	< 0.01
Southeast	0.6241	< 0.01	< 0.01	< 0.01
Southwest	0.013	< 0.01	< 0.01	< 0.01

[1] The comparison between Holsteins and Brown Swiss are not displayed because there were no significant differences.

Table 2.7 Least squares means for number of days lived (SE) and herd-life (SE) up to five years of age in herds with one breed of cows in seven regions.

	Number of days lived			Herd-life		
Region	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey
Northeast	1560 (10.9)	1502 (1.2)	1531 (3.2)	670 (10.9	690 (1.2)	738 (3.2)
North central	1493 (4.3)	1493 (0.52)	1470 (2.8)	621 (4.3)	646 (0.5)	649 (2.8)
Northwest	1523 (5.6)	1503 (0.87)	1515 (2.6)	654 (5.6)	651 (0.9)	697 (2.6)
Central	1522 (11.4)	1522 (0.6)	1589 (2.2)	640 (11.4)	702 (0.6)	802 (2.2)
Southeast	1527 (16.1)	1480 (1.6)	1544 (3.8)	637 (16.1)	633 (1.6)	726 (3.8)
South central	1570 (18.6)	1496 (1.87)	1551 (4.4)	681 (18.7)	658 (1.9)	731 (4.4)
Southwest	1523 (7.7)	1528 (0.58)	1525 (2.5)	658 (7.7)	698 (0.6)	712 (2.5)

Table 2.8 Least squares means for days in lactation (SE) up to five years of age in herds with one breed of cows in seven regions.

Region	Brown Swiss	Holstein	Jersey
Northeast	545 (8.9)	574 (1.0)	612 (2.6)
North central	539 (3.5)	550 (0.4)	551 (2.3)
Northwest	559 (4.6)	566 (0.7)	595 (2.1)
Central	517 (9.3)	585 (0.5)	663 (1.8)
Southeast	539 (13.1)	556 (1.3)	629 (3.1)
South central	587 (15.2)	576 (1.5)	628 (3.6)
Southwest	550 (6.2)	603 (0.5)	613 (2.0)

Table 2.9 Statistical differences using Tukey tests between Brown Swiss (B), Holstein (H) and Jersey (J) cows in herds with one breed for days lived, herd-life and days in milk up to five years of age in seven regions.

	Days Lived			Herd-Life			Days in milk		
Region	B vs. H	B vs. J	H vs. J	B vs. H	B vs. J	H vs. J	B vs. H	B vs. J	H vs. J
Northeast	< 0.01	< 0.01	< 0.01	0.07	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
North central	0.98	< 0.01	< 0.01	< 0.01	< 0.01	0.38	< 0.01	< 0.01	0.86
Northwest	< 0.01	0.07	< 0.01	0.27	< 0.01	< 0.01	0.36	< 0.01	< 0.01
Central	0.96	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Southeast	< 0.01	0.34	< 0.01	0.87	< 0.01	< 0.01	0.16	< 0.01	< 0.01
South central	< 0.01	0.35	< 0.01	0.26	< 0.01	< 0.01	0.40	0.01	< 0.01
Southwest	0.51	0.76	0.31	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

Table 2.10 Risk ratios obtained using Survival analysis for PTA classes of milk, productive life and somatic cell scores in farms with two breeds of cows.

	Holstein-Brown Swiss herds			Holstein-Jersey herds		
Class	PTA milk	PTA pL	PTA scs	PTA milk	PTA pL	PTAscs
1	1.25	1.00	0.98	1.17	1.00	0.97
2	1.00	0.55	1.00	1.00	0.58	1.01
3	0.80	0.26	0.93	0.86	0.33	1.0

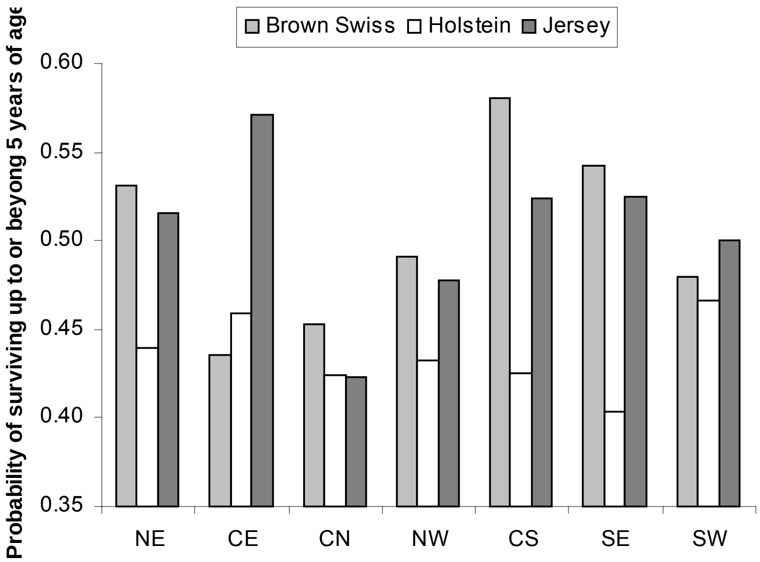

Figure 2.1 Probability estimates for stayability to five years of age in herds with one breed of cows. Jerseys in Southwest are reference with 50% of probability or surviving.

Confidence intervals for herds with one breed for the probability of survival up to or beyond five years of age (stayability).

Regions	Brown Swiss LL[1]	Brown Swiss UL[2]	Holstein LL	Holstein UL	Jersey LL	Jersey UL
Northeast	0.50	0.56	0.43	0.45	0.50	0.53
Central	0.40	0.47	0.45	0.47	0.56	0.58
Central north	0.44	0.47	0.42	0.43	0.41	0.43
Northwest	0.47	0.51	0.43	0.44	0.47	0.49
Central south	0.53	0.63	0.42	0.43	0.51	0.54
Southeast	0.50	0.59	0.40	0.41	0.51	0.54
Southwest	0.46	0.50	0.46	0.47	0.50	0.50

[1] LL = Lower limit

[2] UL = Upper limit

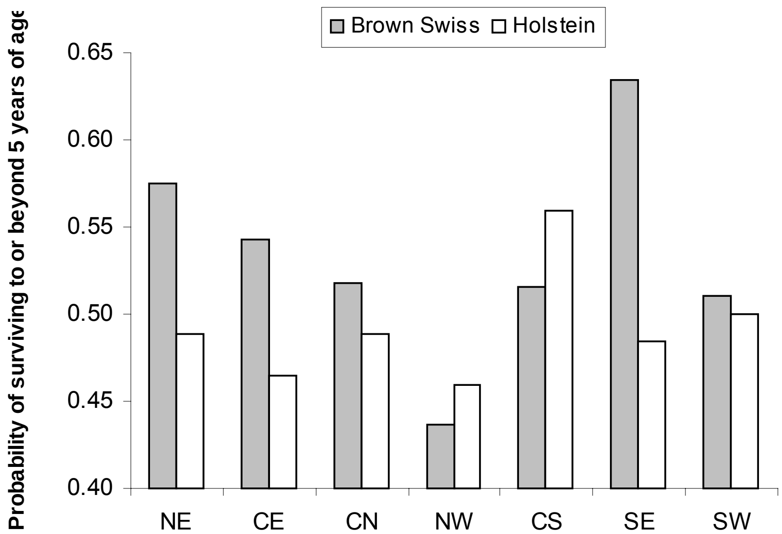

Figure 2.2 Probability estimates for stayability to five years of age in herds with Brown Swiss and Holsteins. Holsteins in Southwest are reference with 50% of probability or surviving.

Confidence intervals for herds with Holsteins and Brown Swiss for the probability of survival up to or beyond five years of age (stayability)

Region	Brown Swiss LL[1]	Brown Swiss UL[2]	Holstein LL	Holstein UL
Northeast	0.54	0.61	0.47	0.51
Central	0.51	0.58	0.44	0.48
Central north	0.49	0.54	0.47	0.51
Northwest	0.28	0.60	0.43	0.48
Central south	0.47	0.56	0.53	0.59
Southeast	0.57	0.69	0.45	0.52
Southwest	0.47	0.55	0.50	0.50

[1] LL = Lower limit

[2] UL = Upper limit

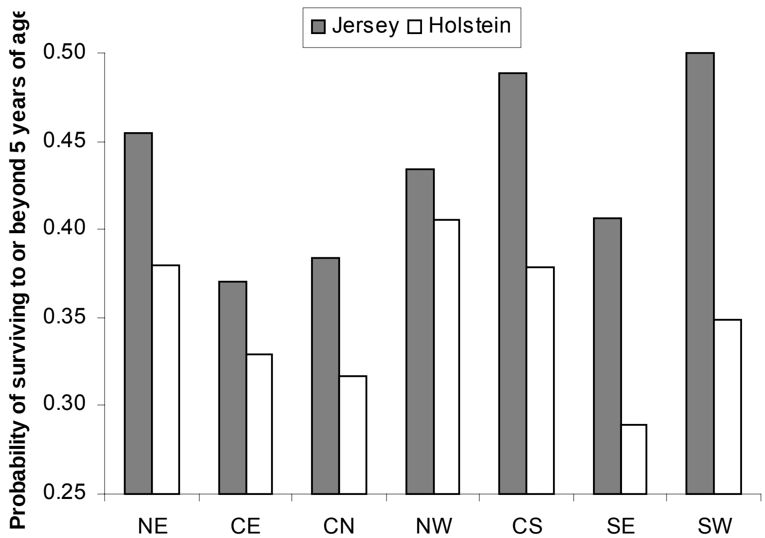

Figure 2.3 Probability estimates for stayability to five years of age in Holstein-Jersey herds. Jerseys in Southwest are reference with 50% of probability or surviving.

Confidence intervals for herds with Holsteins and Jerseys for the probability of survival up to or beyond five years of age (stayability)

Regions	Jersey LL[1]	UL[2]	Holstein LL	UL
Northeast	0.42	0.49	0.36	0.40
Central	0.34	0.41	0.30	0.35
Central north	0.35	0.42	0.29	0.35
Northwest	0.32	0.55	0.37	0.45
Central south	0.43	0.55	0.34	0.41
Southeast	0.37	0.45	0.27	0.31
Southwest	0.50	0.50	0.33	0.37

[1] LL = Lower limit

[2] UL = Upper limit

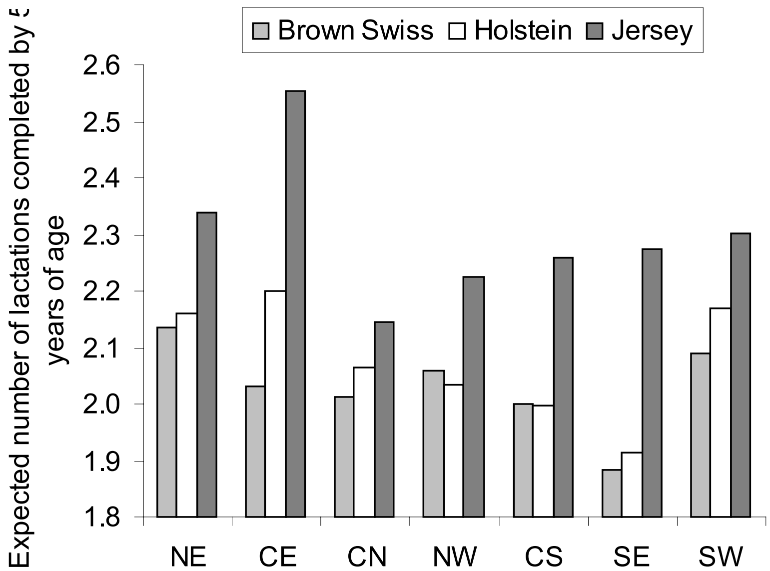

Figure 2.4 Expected number of lactations completed by five years of age in herds with one breed. Jerseys in Southwest are the reference with the overall mean of the Poisson analysis.

Confidence intervals for herds with one breed for number of lactations by 5 years of age.

Regions	Brown Swiss LL[1]	Brown Swiss UL[2]	Holstein LL	Holstein UL	Jersey LL	Jersey UL
Northeast	2.0	2.2	2.1	2.2	2.3	2.4
Central	1.9	2.1	2.2	2.2	2.5	2.6
Central north	2.0	2.1	2.0	2.1	2.1	2.2
Northwest	2.0	2.1	2.0	2.1	2.2	2.3
Central south	1.8	2.2	2.0	2.0	2.2	2.3
Southeast	1.7	2.0	1.9	2.0	2.2	2.3
Southwest	2.0	2.2	2.1	2.2	2.3	2.3

[1] LL = Lower limit

[2] UL = Upper limit

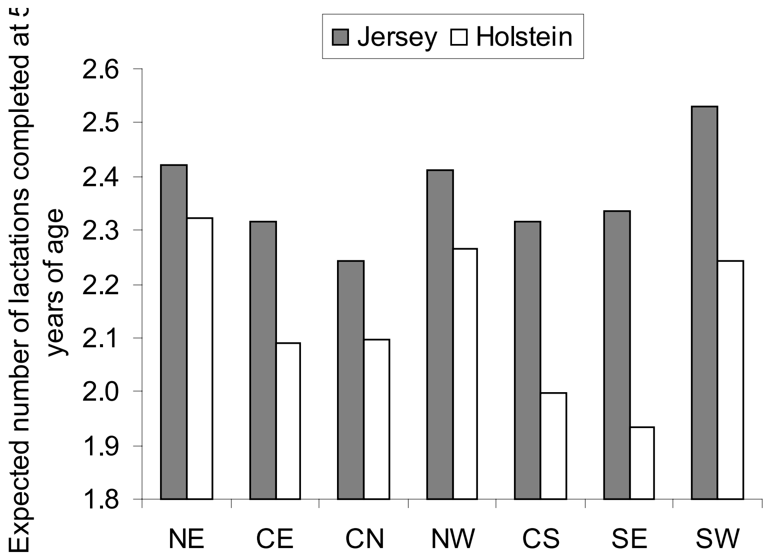

Figure 2.5 Expected number of lactations completed by five years of age in herds with Holstein and Jersey. Jerseys in Southwest are the reference with the overall mean of the Poisson analysis.

Confidence Intervals for herds with Holstein and Jersey cows for number of lactations completed by five years of age

Regions	Jersey		Holstein	
	LL[1]	UL[2]	LL	UL
Northeast	2.3	2.6	2.2	2.5
Central	2.1	2.5	2.0	2.2
Central north	2.1	2.4	2.0	2.3
Northwest	2.0	2.9	2.1	2.5
Central south	2.1	2.6	1.8	2.2
Southeast	2.2	2.5	1.8	2.1
Southwest	2.5	2.6	2.1	2.4

[1] LL = Lower limit

[2] UL = Upper limit

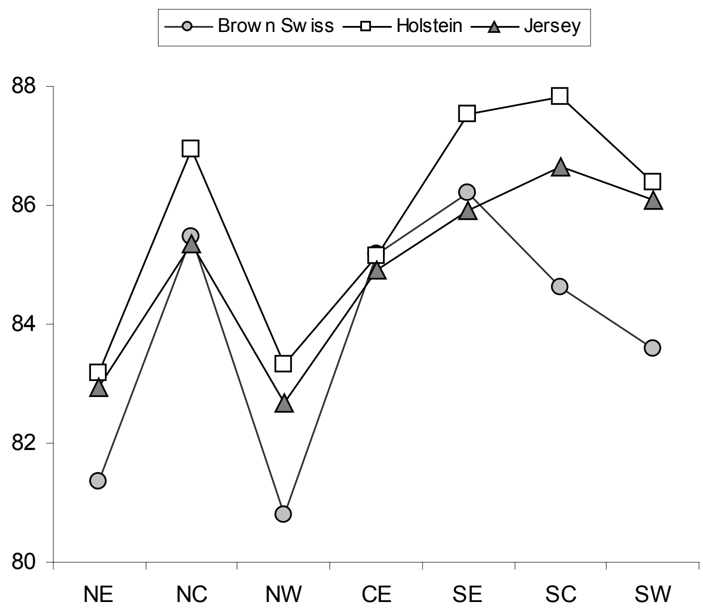

Figure 2.6 Ratio of Days in lactation/Herd-Life up to five years of age in Brown Swiss, Holstein and Jersey cows in seven regions.

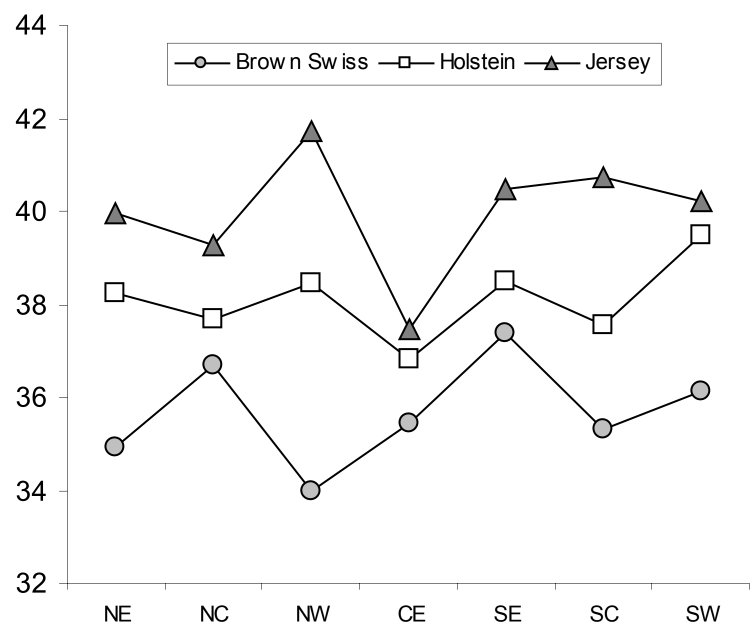

Figure 2.7 Ratio of Days in lactation/Days lived up to five years of age in Brown Swiss, Holstein and Jersey cows in seven regions.

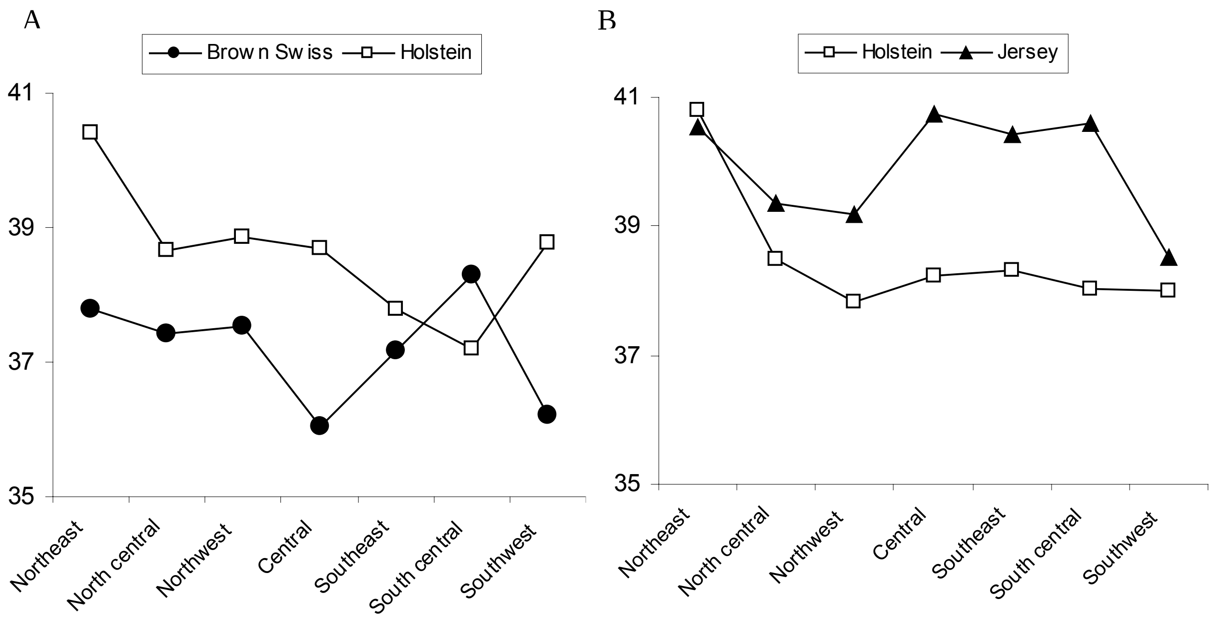

Figure 2.8 Ratio of Days in lactation/Days lived up to five years of age in Holstein-Brown Swiss and Holstein-Jersey herds

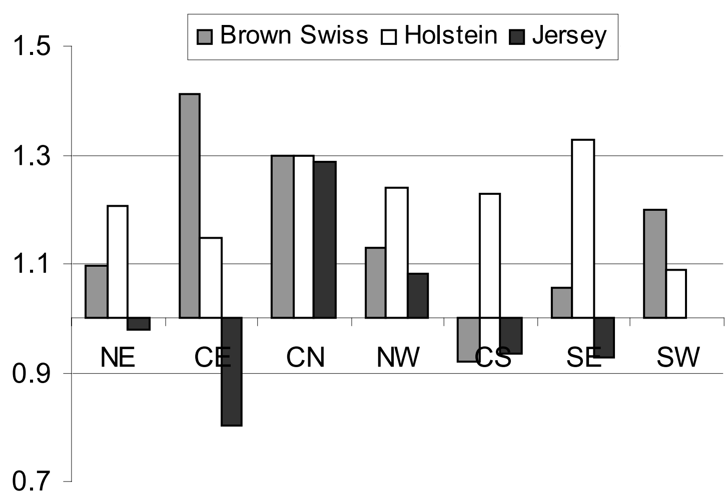

Figure 2.9 Risk ratios assessed by Survival Analysis, for Brown Swiss, Holstein and Jersey cows in herds with one breed of cows, in seven regions. Jerseys in Southwest are the reference.

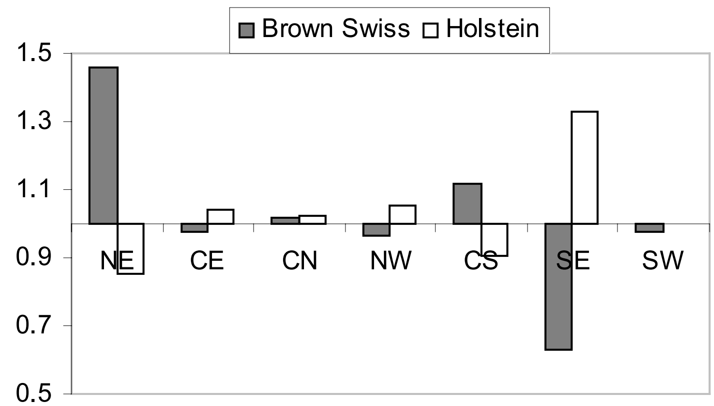

Figure 2.10 Risks ratios for Holstein-Brown Swiss herds in seven regions. Holsteins in Southwest are the reference.

Appendix

Including herd-size classes and the interaction of herd-size by breed in the analyses of Days lived, Herd-life and Days in lactation up to five years of age in herds with one breed

A question aroused as whether fitting herd-size classes would modify the outcome of the breed, region, and breed by region interaction effects. To answer this question, several herd-size classes were fitted to the dataset of herds with one breed, using equation iii) augmented by herd-size classes. I found that medium and large herd-sizes with 26 or more births per year were not significantly different for the three breeds (Brown Swiss, Holstein and Jersey) and for the three traits (DL5, HL5, and DIM5). However, the smaller herd-size classes were significantly different from the larger herd-size classes. Three classes were finally fitted. Class 1 had an average of 10 or less births per year of the cows included in the dataset, class 2 included herds with an average of 11 to 25 births per year, and class 3 comprised herds with 26 or more births per year.

The number of cows per breed per class is presented in Table 2.11.

Table 2.11 Number of cows per breed per herd-size class

Herd-size class[1]	Brown Swiss	Holstein	Jersey
1	6911	315,696	24,703
2	6431	598,039	28,815
3	1823	880,217	50,699

[1] Herd-size determined by average number of births of calves per year: Class 1) 1-10, class 2) 11-15, and class 3) 26 or more births of calves per year.

The effects of herd-size class and the interaction of class by breed were significant, as well as the effects fitted previously: breed, region, and breed by region interaction. The least squares means and the paired differences obtained for breed by herd-size class interactions from these analyses are presented in Table 2.12.

Table 2.12 Least squares means (SE) and paired differences for herd-size-class by breed interaction in herds with one breed for Days lived, Herd-life, and Days in lactation at 5 years.

Trait	Herd-size[1]	Brown Swiss	Holstein	Jersey	B vs. H	B vs. J	H vs. J
Days lived							
	1-10	1505 (5.5)	1476 (0.8)	1481 (2.4)	< 0.01	< 0.01	0.05
	11-25	1543 (5.9)	1510 (0.7)	1518 (2.1)	< 0.01	< 0.01	0.18
	> 25	1569 (8.3)	1509 (0.6)	1573 (1.7)	< 0.01	0.62	< 0.01
Herd-life							
	1-10	624 (5.5)	614 (0.8)	641 (2.4)	0.09	< 0.01	< 0.01
	11-25	676 (2.4)	662 (0.7)	701 (2.1)	0.02	< 0.01	< 0.01
	>25	681 (8.3)	689 (0.6)	777 (1.7)	0.50	< 0.01	< 0.01
Days in lactation							
	1-10	522 (4.5)	526 (0.6)	541 (2.0)	0.39	< 0.01	< 0.01
	11-25	570 (4.8)	569 (0.5)	599 (1.7)	0.80	< 0.01	< 0.01
	> 25	575 (6.8)	592 (0.4)	661 (1.4)	0.01	< 0.01	< 0.01

[1] = Average number of births per year of the data used.

Table 2.12 shows that larger herd-sizes tend to produce larger values for the three traits considered (DL5, HL5, and DIM5). However, in all the cases, the same trends that were found in the previous analyses are found for these supplemental analyses, i.e. Brown Swiss and Jerseys obtained larger values than Holsteins for DL5, Brown Swiss and Holsteins were often not significantly different for HL5, and not significantly different for DIM5. In agreement with previous findings, Jerseys had larger least squares means for the three traits in the three herd-size classes. The analyses fitting herd-size classes gave very similar results for breed, region, and breed by region interaction effects, in general maintaining the trends previously found (without fitting herd-size classes). Figures 2.11, 2.12, and 2.13 show the trends using the models fitting herd-size classes, which are similar to results previously presented in Tables 2.7 and 2.8.

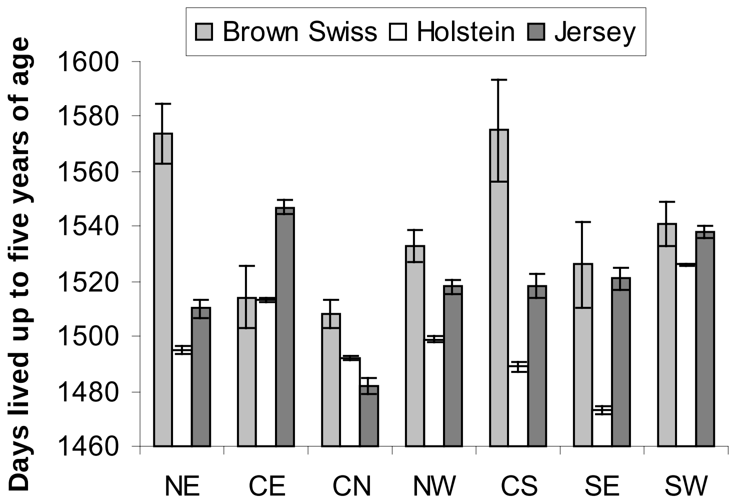

Figure 2.11 Least squares means for breed by region effect on Days lived up to five years of age in herds with one breed using an analysis fitting herd-size classes.

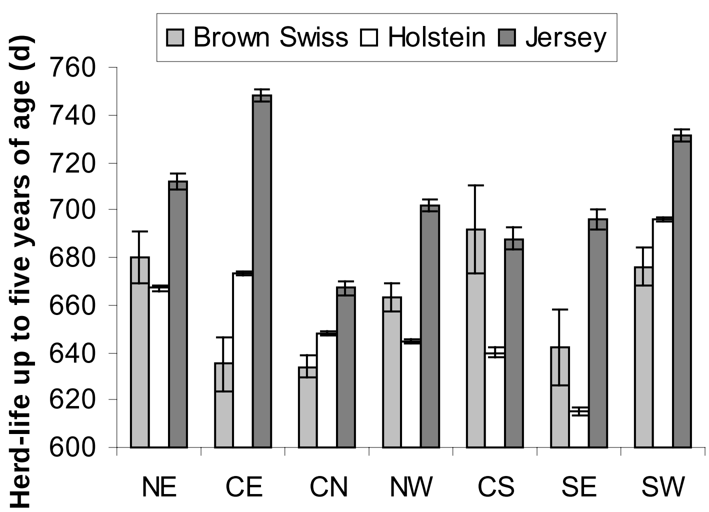

Figure 2.12 Least squares means for breed by region effect on Herd-life up to five years of age in herds with one breed using an analysis fitting herd-size classes.

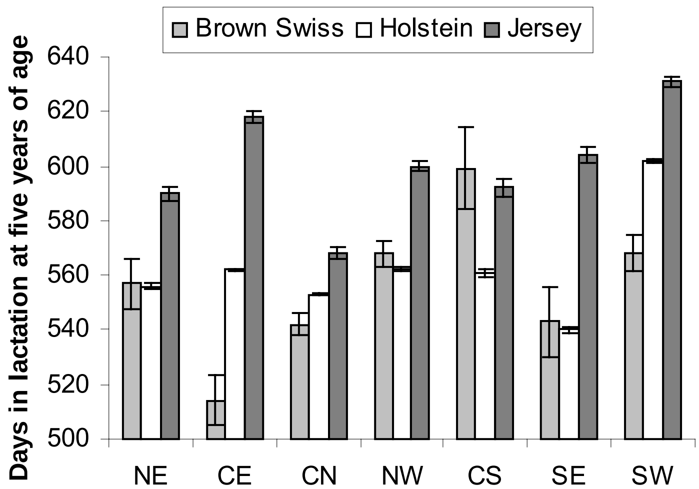

Figure 2.13 Least squares means for breed by region effect on Days in lactation at five years of age in herds with one breed using an analysis fitting herd-size classes.

The effects of herd-size on DL5, HL5, and DIM5 are most likely due to management differences, and the different assets the farms had. Larger herds are likely to have more assets. Further research on how management affects longevity traits is justified.

CHAPTER V

General Conclusions and Implications

GENERAL CONCLUSIONS AND IMPLICATIONS

Jerseys, and to a lesser extent, Brown Swiss showed evidence of heat-stress resistance relative to Holsteins, for age at first calving and first calving interval. Longer calving intervals and older ages at first calving were not likely due entirely to effects of heat-stress on fertility, but also to intentional voluntary waiting period to breed heifers or rebreed cows. Breed by season interactions were found for age at first calving and fist calving interval.

There was indirect evidence of heat abatement practices in some states. Whenever or wherever heat-stress is likely a concern, such practices, along with overall better management, can help control fertility traits.

Jerseys, and to a lesser extent Brown Swiss, also showed advantages over Holsteins for the longevity-related traits studied. Brown Swiss showed good longevity performance, but their older ages at first calving limit the speed of return when it is evaluated up to five years of age, and probably is carried all through their lifetime. However, economic research would be needed to observe in the long-run which is the most profitable breed for each region, since breed by region interaction was always present for the fitness traits studied here, However, the definition of regions should still be a matter of study.

The evaluation of specific traits in a particular place and timeframe is useful for comparison purposes. Comparison of breeds against their time-space-cohorts yields information for several important decision-making issues. Some decisions relate to the primary objectives of selecting sires for future generations. The analysis of the fitness trends in dairy populations should be of great concern. The genetic pool of available least related sires is fast reducing; therefore, selection is performed within a small population size, with the inevitable result of diminished genetic diversity. Once genes are lost, retrieving those turns impossible, even if crossbreeding is performed. The implementation of a somewhat less intensive selection for production, or giving credit for sires being less related to the average population, might result in stronger animals that require less health care costs, and reduce costs for replacing cows.

Further research on overall survival, reproduction, and health using adequate methods is advisable.

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VITA

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