Effects of Breed and Region on Longevity Traits Through Five Years of Age in Brown Swiss, Holstein, and Jersey Cows in the United States

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ABSTRACT

The objective of this study was to assess breed, and breed $\times$ region interactions for several longevity-related traits, measured up to 5 yr of age in Brown Swiss, Holstein, and Jersey cows in 7 regions of the United States. Data were analyzed using logistic, poisson, and linear models, and survival analyses. The traits were stayability (yes/no survived to 5 yr of age), number of completed lactations, days lived, herd-life, and days in milk (DIM) to 5 yr of age. Probable lifetime DIM were also estimated using data from the first 5 yr of age of the cows. Herd-life was defined as the days lived up to 5 yr of age minus the age at first calving. Days in milk consisted of herd-life up to 5 yr of age minus the dry periods. Three data files were analyzed: herds with one breed of cows, herds with Holstein and Brown Swiss, and herds with Holstein and Jersey cows. Breed $\times$ region interaction was usually significant, with larger effects for the southern regions. Jerseys obtained largest values for the ratio of DIM to days lived, and for the number of completed lactations to 5 yr of age. Brown Swiss had the largest probabilities of surviving to 5 yr of age (stayabilities) in all regions. For the other traits, the results for Brown Swiss were inconsistent, but usually the cows of this breed had shorter herd-life and DIM to 5 yr of age than Holsteins. Brown Swiss cows were expected to have more total DIM in their lifetime in the Southeast than Holsteins. Survival analysis gave the most readily interpretable information, although the linear, poisson, and logistic analyses answered slightly different questions. Adjustment for herd size did not modify the results.

Key words: breed comparison, region, survival

INTRODUCTION

Many producers have well-defined comparisons of dairy breeds in the United States 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 (van Arendonk, 1991; Jagannatha et al., 1998). Longevity traits can be described as binary stayability (either did or did not live to a specific age), countable (lactations, years), or quasicontinuous (days, months). Stayabilities and number of lactations are categorical traits, and can be evaluated using logistic and poisson models, respectively (Stokes et al., 2000; Agresti, 2002). Genetic and phenotypic correlations between longevity evaluations from different countries range from moderate to high (60 to 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 $\times$ region interactions for longevity-related traits in dairy cows have not been thoroughly studied.

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 for replacing from the third to the tenth lactation. Loss of profit was very significant for cows with only 1 or 2 lactations (Mason, 2004). A cow with 3 lactations should be about 5 yr old. Studying the first 5 yr of life of cows would give an insight into what they have accomplished at that possible threshold of productivity. A cow living past that age can increase her value through later lactations and would be more valuable with higher replacement costs.

Intra-herd reasons for disposal change through time (Westell et al., 1982). Studying outcomes from cow populations with only a few birth-years results in a more homogeneous population.

The present study evaluated the performance during 5 yr of life opportunity of cows born from January 1992 to June 1996 for longevity-related traits not adjusted by milk production. The data were obtained from Holstein, Brown Swiss, and Jersey herds, and from herds with 2 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, whereas herds with

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2 breeds of cows offer a direct comparison of the breeds involved because a common environment influences management decisions and breed performance. The objectives of this study were to compare those breeds, using information from the first 5 yr of age, for stayability to 5 yr, number of completed lactations, days lived, herd-life, and DIM up to 5 yr of age (1,825 d), as well as to estimate the probable lifetime DIM, and to assess the breed $\times$ region interactions for 7 regions of the United States.

MATERIALS AND METHODS

The data were provided by the Animal Improvement Programs Laboratory, USDA-ARS (Beltsville, MD), and included individual cow test-day records from all the Jersey and Brown Swiss cows in the United States, and test-day records of all the Holstein cows in herds with the same zip code as Brown Swiss or Jersey herds. From these data, only herds that reported calvings from January 1995 to June 2001 were used. It was required that the cows stayed in the same herd throughout the 5 yr of life opportunity (1,825 d) or until culling. At the end of the 5-yr opportunity, the data on individual cows were truncated. The maximum age at first calving allowed was 3 yr (1,095 d).

Three data files were analyzed: herds with single breeds of Brown Swiss, Holstein, and Jersey; herds with both Holstein and Brown Swiss (**HB**); and herds with both Holstein and Jersey (**HJ**). The data for herds with 1 breed included 15,165 cows on 1,308 Brown Swiss farms, 1,793,952 cows on 27,906 Holstein farms, and 104,217 cows on 3,309 Jersey farms. The data for herds with 2 breeds included 26,469 Holstein and 4,697 Brown Swiss cows on 223 HB farms, and 23,937 Holstein and 6,791 Jersey cows on 250 HJ farms.

The country was divided into 7 regions: Northeast (Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Delaware, Maryland, New Jersey, Rhode Island, and Vermont), North Central (Michigan, Wisconsin, Iowa, Minnesota, North Dakota, and South Dakota), Northwest (Idaho, Washington, Wyoming, Montana, and Oregon), Central (Ohio, Indiana, Illinois, Kansas, Nebraska, Missouri, Kentucky, Tennessee, Virginia, and West Virginia), Southeast (Florida, Georgia, South Carolina, North Carolina, Alabama, and Mississippi), South Central (Texas, Oklahoma, Arkansas, and Louisiana), and Southwest (Colorado, New Mexico, Arizona, Utah, Nevada, and California). Table 1 shows the number of cows per data file and region.

More than 80% of the Brown Swiss and Holstein cows in herds with 1 breed were in 3 regions: North Central, Southwest, and Northwest for Brown Swiss, and North

Central, Southwest, and Central for Holstein. The Jersey herds and the cows in herds with 2 breeds were more evenly distributed (Table 1).

The traits analyzed were stayability (did or did not survive to 5 yr of age), number of completed lactations (**LAC5**), days lived (**DL5**), herd-life (**HL5**), and DIM (**DIM5**) up to 5 yr of age (1,825 d). Probable lifetime DIM (**TDIM**) was also studied. Herd-life was defined as DL5 minus age at first calving. Both DIM5 and TDIM consisted of HL5 minus the dry periods, and were obtained by adding the DIM per lactation until 1,825 d of age of the cows; thus, DIM beyond 305 d were included. The difference between DIM5 and TDIM was that for TDIM, the data from cows still alive at 5 yr of age were considered censored, with unknown date of stopping accumulating DIM. Stayability and LAC5 were analyzed with the GENMOD procedure of SAS (SAS Institute, Inc., Cary, NC) with the CONTRAST statement used to test significance of differences between specific pairs of variables. Days lived to 5 yr of age, HL5, and DIM5 were analyzed with the MIXED procedure of SAS (Littell et al., 1996). Probable lifetime DIM were analyzed using survival analysis (Ducrocq and Solkner, 2000). Likelihood ratio tests were used to test significance of breed $\times$ 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. Table 2 shows raw means for the traits analyzed, except TDIM.

The Animal Improvements Program Laboratory provided the cow predicted transmitting ability values (**cPTA**) from the February 2003 evaluation for the 2-breed herds. Three classes for cPTA milk, SCS, and productive life were obtained by adding and subtracting half the standard deviation of cPTA to the average cPTA value (per breed, per data file); the cows inside this range were class 2. Class 1 included cows below that range; and class 3, the cows with larger values. Similar numbers of cows per data file were in each class. These cPTA classes were fitted in the survival analysis of TDIM for herds with 2 breeds of cows.

The data were analyzed with 4 models: logistic, poisson, linear, and survival analysis. Birth year-season group, breed, region, and breed $\times$ region interaction were fitted in all the models. Additional factors were fitted in the linear and survival analysis models for the 2-breed herds. Stayability was analyzed using a logistic model, LAC5 using a poisson model, and DL5, HL5, and DIM5 were analyzed with linear models. In data from herds with 2 breeds, herd nested in region was added.

Days lived to 5 yr of age, HL5, and DIM5 were also analyzed by including a herd size class effect, using

Table 1. Number of cows per region in the 3 data files of this study

Region ³	Herds with 1 breed of cows ¹			Herds with 2 breeds of cows ²			
	Brown Swiss	Holstein	Jersey	Brown Swiss and Holstein		Jersey and Holstein	
NE	1,026	87,201	11,534	722	4,842	1,603	7,941
NC	6,601	588,776	15,391	1,602	4,836	880	1,641
NW	3,762	176,123	17,867	37	1,984	73	852
CE	923	397,466	25,408	930	3,362	1,080	3,350
SE	464	49,109	8,448	234	1,053	883	3,788
SC	343	35,744	6,202	472	1,399	312	1,058
SW	2,046	459,533	19,367	700	8,993	1,960	5,307

¹Data file 1.²Data files 2 and 3: Holstein-Brown Swiss and Holstein-Jersey herds.³NE = Northeast, NC = North Central, NW = Northwest, CE = Central, SE = Southeast, SC = South Central, SW = Southwest.

the data from the 3 data files. Several herd sizes (that formed 3 to 6 classes) were tested. Medium and large herd sizes (with 26 or more births per year per herd) were not significantly different for the 3 traits (DL5, HL5, and DIM5) in any of the 3 files. For this reason, 3 classes were fitted: class 1, with an average of 10 or fewer births per year (6,911 Brown Swiss, 315,696 Holsteins, and 24,703 Jersey); class 2 with herds with an average of 11 to 25 births per year (6,431 Brown Swiss, 598,039 Holstein, and 28,815 Jersey), and class 3 comprised herds with 26 or more births per year (1,823 Brown Swiss, 880,217 Holstein, and 50,699 Jersey). Larger herd sizes usually produced larger values for DL5, HL5, and DIM5. However, the same trends for breed, region, and their interaction were found in the analyses with or without herd size, and the model fit did not improve significantly.

Survival analysis was used for TDIM. In this case, the proportional hazard (or instantaneous rate) of stopping accumulating DIM was due to death or removal, influenced by the effects of the same factors fitted in the linear models, but with the addition of cPTA classes for herds with 2 breeds; the baseline hazard was assumed to follow a Weibull distribution. The baseline can be summarized by 2 parameters: ρ and λ , for shape

and scale, respectively, but usually only ρ is documented. When $\rho < 1$, the hazard reduces with time; when $\rho > 1$, the hazard increases with time.

No breed differences for any trait were found for the 2-breed herds in the Northwest, probably due to the relatively few Brown Swiss and Jersey cows in that region. Those results will not be discussed.

RESULTS

In herds with a single breed, Brown Swiss and Jerseys were not statistically different for stayability, measured as the probability to survive to 5 yr, or for DL5, measured as the number of days lived until death, culling, or 5 yr of age. Both Brown Swiss and Jersey cows had larger values for stayability and DL5 than Holsteins. In 2-breed herds, there were no significant breed differences for any trait between Holsteins and Brown Swiss and breed $\times$ region interaction was not significant for LAC5. Some more detailed results follow.

Stayability

In herds with one breed, there were significant differences for the effects of breed, region, and their interac-

Table 2. Averages (SD) of the traits analyzed for the 3 data files in this study

Trait ¹	Herds with 1 breed			Herds with 2 breeds			
	Brown Swiss	Holstein	Jersey	Holstein and Jersey		Brown Swiss and Holstein	
AFC	855 (98.5)	814 (95.7)	784 (97.5)	807 (100.3)	808 (97.4)	847 (96.9)	798 (87.8)
STAY	0.42 (0.49)	0.38 (0.49)	0.45 (0.50)	0.42 (0.49)	0.51 (0.50)	0.47 (0.52)	0.43 (0.49)
LAC5	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	1,509 (344.8)	1,503 (341.2)	1,528 (350.2)	1,542 (323.6)	1,587 (320)	1,564 (323)	1,547 (323.3)
HL5	653 (343.5)	689 (342.6)	743 (355.4)	735 (324.7)	779 (323.1)	717 (326.4)	749 (327)
DIM5	554 (280.2)	592 (280.3)	633 (290.7)	628 (267.2)	660 (269.7)	606 (267.4)	634 (266.5)

¹AFC = Age at first calving; trait not included as an outcome in the analyses; STAY = stayability or survival (yes/no) at 5 yr of age; LAC5 = number of lactations completed by 5 yr of age; DL5 = days lived up to 5 yr of age; HL5 = herd-life to 5 yr of age; and DIM5 = number of DIM at 5 yr of age.

Figure 1. Probability of surviving to 5 yr of age (stayability) of Brown Swiss, Holsteins, or Jerseys in herds with one breed of cows by region (NE = Northeast, NC = North Central, NW = Northwest, CE = Central, SE = Southeast, SC = South Central, SW = Southwest). Vertical lines represent confidence interval ranges. Jerseys in Southwest were the reference with 50% probability of surviving.

tion ($\chi^2 P < 0.01$) for stayability. Brown Swiss obtained the largest stayabilities in most regions, except the Central and Southwest, where Jerseys were better (Figure 1). Breed $\times$ region interaction contrasts between Brown Swiss and Jersey were significant only in the 3 central regions ($\chi^2 P < 0.01$ for Central and North Central, and $P = 0.04$ for South Central). Holstein usually had the lowest stayabilities ($\chi^2 P < 0.01$) compared with Brown Swiss or Jersey. The differences of Holstein with the other breeds were larger than 15% in South Central and Southeast (Figure 1) regions, likely because of heat stress.

On HJ farms, Jerseys had larger stayability values than their Holstein herdmates in all regions ($\chi^2 P < 0.01$), with larger differences in South Central, Southeast, and Southwest (Figure 2). On HB farms, Brown Swiss outlived ($\chi^2 P < 0.01$) Holsteins in Northeast, Central, and Southeast (Figure 2).

Number of Lactations Completed by Five Years of Age

In herds with one breed, significant differences ($\chi^2 P < 0.01$) were detected for breed, region, and their interaction for LAC5. The breed trend for LAC5 was clear, with Jerseys likely to have more LAC5 than Holsteins, and Holsteins slightly more than Brown Swiss in all regions (Figure 3). The Jerseys in the Central region had the highest LAC5 value: 2.6 lactations completed by 5 yr of age. The lowest value was less than 2

Figure 2. Probability of surviving to 5 yr of age (stayability) in herds with Brown Swiss and Holsteins (top) or Jerseys and Holsteins (bottom) by region (NE = Northeast, NC = North Central, NW = Northwest, CE = Central, SE = Southeast, SC = South Central, SW = Southwest). Vertical lines represent confidence interval ranges. Holsteins (for the Holstein-Brown Swiss herds) and Jerseys (for the Holstein-Jersey herds) in Southwest were the references with 50% probability of surviving.

lactations completed for both Holsteins and Brown Swiss in the Southeast.

On HJ farms, the Jersey cows were likely to have more LAC5 than the Holsteins ($\chi^2 P < 0.01$), with greater differences between breeds in Central (2.3 vs. 2.1 likely lactations), Southwest (2.5 vs. 2.2), South Central (2.3 vs. 2), and Southeast (2.3 vs. 1.9) (data not shown).

Days Lived, Herd-Life, and DIM to Five Years of Age

Days Lived. In herds with one breed, the Brown Swiss cows obtained more DL5 than the Holsteins or

Figure 3. Expected number of lactations completed by 5 yr of age for Brown Swiss, Jerseys, and Holsteins in herds with one breed by region (NE = Northeast, NC = North Central, NW = Northwest, CE = Central, SE = Southeast, SC = South Central, SW = Southwest). Vertical lines represent confidence interval ranges. Jerseys in Southwest were the reference with the overall mean of the poisson analysis.

Jerseys in most regions. Least squares means for breed were usually less for Holstein than either Brown Swiss or Jersey, with largest differences in Northeast and South Central with respect to Brown Swiss, and Central and Southeast with respect to Jersey (Table 3). In the Southwest, the 3 breeds performed similarly.

On HJ farms, Jerseys always lived longer ($P < 0.01$ for DL5 breed effect) than their Holstein herdmates (not shown). However, the breed $\times$ region interaction effects were not significant in the Northern regions

(Northeast $P = 0.07$; North Central $P = 0.08$; Northwest $P = 0.52$). On HB farms, Brown Swiss had larger values for DL5 than Holstein ($P < 0.01$) in North Central ($1,574 \pm 9.9$ d vs. $1,542 \pm 7.9$ d), Central ($1,583 \pm 12.2$ d vs. $1,540 \pm 8.9$ d), and Southeast ($1,657 \pm 22.1$ d vs. $1,573 \pm 12.6$ d), with no significant breed $\times$ region differences elsewhere.

Herd-Life. The Jersey breed had the longest ($P < 0.01$) HL5 (the interval from first calving to death, culling, or 5 yr of age) in all regions for herds with one breed of cows (Table 3). For HL5, Brown Swiss and Holsteins were not significantly different in the same regions where Brown Swiss had significantly larger values of DL5 than Holsteins (Table 3); that is, Northeast, Northwest, Southeast, and South Central. This result was probably due to older ages at first calving for Brown Swiss, because the difference between DL5 and HL5 is age at first calving.

On HJ farms, the trend to larger values of HL5 for Jersey was significant only in Central ($P = 0.05$ with 42-d difference) and Southeast ($P < 0.01$ with 83-d difference) regions. In HB herds, the breed $\times$ region interaction was significant only for Southwest (700 ± 14.7 d for Brown Swiss vs. 748 ± 8.2 d for Holstein).

DIM. For the variable DIM5, measured as the DIM accumulated from first calving to death, culling, or 5 yr of age, Jerseys generally had the most DIM5 and Brown Swiss had the least (Table 3) in herds with one breed. There were larger differences between the Jersey and Holstein breeds in Central, Southeast, and South Central regions (78, 73, and 52 d, respectively), regions where heat stress is most likely. Likewise, in herds with 2 breeds, the Holstein cows usually had less DIM5

Table 3. Least squares means for number of days lived (SE), herd-life (SE), and DIM (SE) up to 5 yr of age in herds with 1 breed of cows in 7 regions

Region	Number of days lived			Herd-life			DIM		
	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey
Northeast	1,560 ^a (10.9)	1,502 ^b (1.2)	1,531 ^c (3.2)	670 ^{a*} (10.9)	690 ^{a*} (1.2)	738 ^b (3.2)	545 ^a (8.9)	574 ^b (1.0)	612 ^c (46)
North Central	1,493 ^a (4.3)	1,493 ^a (0.5)	1,470 ^b (2.8)	621 ^a (4.3)	646 ^b (0.5)	649 ^b (2.8)	539 ^a (3.5)	550 ^b (0.4)	551 ^b (2.3)
Northwest	1,523 ^{a*} (5.6)	1,503 ^b (0.9)	1,515 ^{a*} (2.6)	654 ^a (5.6)	651 ^a (0.9)	697 ^b (2.6)	559 ^a (4.6)	566 ^a (0.7)	595 ^b (2.1)
Central	1,522 ^a (11.4)	1,522 ^a (0.6)	1,589 ^b (2.2)	640 ^a (11.4)	702 ^b (0.6)	802 ^c (2.2)	517 ^a (9.3)	585 ^b (0.5)	663 ^c (1.8)
Southeast	1,527 ^a (16.1)	1,480 ^b (1.6)	1,544 ^a (3.8)	637 ^a (16.1)	633 ^a (1.6)	726 ^b (3.8)	539 ^a (13.1)	556 ^a (1.3)	629 ^b (3.1)
South Central	1,570 ^a (18.6)	1,496 ^b (1.9)	1,551 ^a (4.4)	681 ^a (18.7)	658 ^a (1.9)	731 ^b (4.4)	587 ^a (15.2)	576 ^a (1.5)	628 ^b (3.6)
Southwest	1,523 ^a (7.7)	1,528 ^a (0.6)	1,525 ^a (2.5)	658 ^a (7.7)	698 ^b (0.6)	712 ^c (2.5)	550 ^a (6.2)	603 ^b (0.5)	613 ^c (2.0)

^{a-c}Values with the same letter are not significantly different; values with different letters are different ($P < 0.01$).

*These quantities approach significance ($P = 0.07$).

than the Jerseys, with the largest difference in the Southeast ($P < 0.01$ with 656 ± 10.4 d for Jersey vs. 587 ± 6.5 d for Holstein). Jersey had the highest percentage of DIM5 to DL5 in the 3 data files, followed by Holstein.

On HB farms, Holsteins usually had more DIM5 than Brown Swiss, although differences were significant only in the Northeast ($P = 0.03$ with 635 ± 5.8 d for Holstein vs. 591 ± 11.1 d for Brown Swiss) and Southwest ($P < 0.01$ with 610 ± 5.6 d for Holstein vs. 561 ± 11.7 d for Brown Swiss) regions. However, in the Southeast, Brown Swiss had 48 d more DIM5 than Holstein.

Probable Lifetime DIM

The results from survival analyses are interpreted differently than those of the logistic and poisson analyses. Survival analysis presents relative risks of failure. In this case, the risk would be failure to continue accumulating DIM. The logistic and poisson analyses, respectively, give probabilities of survival or the expected number of lactations to 5 yr of age achieved by each group compared with the reference. Thus, for stayability or LAC5, a positive value indicates that the group of interest has greater probability of surviving or completing more lactations to 5 yr of age than the reference group. On the contrary, in survival analysis, a positive value means the group under analysis has more risk than the reference. In this study, it could mean less probability of accumulating DIM than the reference group. Group differences, in these cases, are multiplicative. Least squares means from linear models are the means that would be expected in a balanced design, and represent additive group differences, without a reference.

In herds with one breed of cows, breed, region, breed $\times$ region interaction, and birth year-season were significant ($\chi^2 P < 0.01$). The ρ parameter was 1.36 when the full model or the model without main effects (only including interactions) was run. Therefore, the shape of the distribution was similar in the full model, and in the model fitting only interactions; in both of them, the risk of failure increased with time. Thirty-nine percent of the records were right censored, which means the cows were still alive at 5 yr of age. The average censoring time of these records was 837 d (DIM), and the maximum time was 1,214 d. Uncensored records (corresponding to cows that died before achieving 5 yr of age) had an average failure time of 439 d, and a maximum failure time of 1,201 d.

The region with the largest TDIM average was Southwest with 619 d, compared with the lowest TDIM average in North Central of 567 d. The TDIM averages for the breeds were: 554 d for Brown Swiss, 592 d for Holstein, and 633 d for Jersey.

Figure 4. Risk ratios assessed by survival analysis for Brown Swiss, Holstein, and Jersey cows in herds with one breed in 7 regions (NE = Northeast, NC = North Central, NW = Northwest, CE = Central, SE = Southeast, SC = South Central, SW = Southwest). The Jersey breed in Southwest was the reference.

The risk ratios for breed and region are depicted in Figure 4. Lower values mean lower risk or longer TDIM to attain, in this case; that is, Brown Swiss in Northeast had a risk of 1.1, meaning their risk was 10% higher than the reference. Jerseys in the Southwest were the reference, with a risk of 1.0. Holsteins and Brown Swiss usually had higher risks than Jerseys, except that Brown Swiss was close to Jerseys in South Central and the 3 breeds had very similar risks in North Central. These results are in general agreement with the linear model analysis for DIM5 (Table 3): Brown Swiss' DIM5 were fewest in the Central region (where Brown Swiss had the highest risk), and most in the South Central (where Brown Swiss had their lowest risk); Jersey, with more DIM5 than the other breeds, had the least risk for all regions (Table 3 and Figure 4). However, risks for Holsteins were larger than for Brown Swiss in Northeast, Northwest, South Central, and Southeast (Figure 4). In Table 3, Holsteins show more DIM5 than Brown Swiss in all regions, except South Central. The survival analysis could detect that in those regions Brown Swiss had an advantage in stayability, and lived significantly longer than Holstein, as was shown in Figure 1. Thus, the additional information used by survival analysis resulted in Brown Swiss' improved risk levels for some regions.

For the HB farms, the ρ parameter was 1.64 for the full model, the model without main effects, and for a preliminary analysis (full model) in which sire variance was included using relationships in a sire-maternal grandsire model. The significance of all estimates was unchanged whether considering the sire variance (in the preliminary analysis) or not. The effect of breed was not significant ($\chi^2 P = 0.45$), but region, the interac-

Figure 5. Risks ratios for Holstein-Jersey herds in 7 regions (NE = Northeast, NC = North Central, NW = Northwest, CE = Central, SE = Southeast, SC = South Central, SW = Southwest). The Holsteins in Southwest were the reference.

tion of breed $\times$ region, and the cPTA classes for milk, productive life, and SCS were significant ($\chi^2 P < 0.01$).

For HJ farms, the ρ parameter was 1.69 for both the full and the model without main effects. Breed, region, breed $\times$ region, and the cPTA classes for milk and productive life were significant ($\chi^2 P < 0.01$), but not the cPTA class for SCS ($\chi^2 P = 0.14$).

Overall, the Jerseys had 26% lower risk (more TDIM) than the Holstein cows. Risk ratio differences were more important in Northeast, Central, and Southeast between the Holstein and Jersey cows (Figure 5). The risk ratios for HB farms, by region, are depicted in Figure 6, in which it is clear that Brown Swiss had highest risks in Northeast (where Brown Swiss had significantly less DIM5 than Holstein), and lowest in Southeast (where Brown Swiss had the highest stayability for HB farms). The risk ratios for both types of

Figure 6. Risks ratios for Holstein-Brown Swiss herds in 7 regions (NE = Northeast, NC = North Central, NW = Northwest, CE = Central, SE = Southeast, SC = South Central, SW = Southwest). Holsteins in Southwest were the reference.

farms for the cPTA classes are presented in Table 4. Higher cPTA classes for milk or for productive life reduced the risk (and allowed more TDIM, in this case). The results for SCS were contradictory for HB farms, in the sense that both the lower and higher classes had lower risks than the intermediate class. Perhaps SCS were related to milk production; VanRaden and Seykora (2003) reported a genetic correlation of 0.2.

DISCUSSION

In general, the information obtained using data from either 1- or 2-breed herds leads to the same conclusions with respect to the comparison of Holstein with Jersey or Brown Swiss. However, fewer significant differences were obtained using the 2-breed herds' data.

The breed $\times$ region interaction was often significant, but consistent results usually involved the Southern regions.

The Brown Swiss and Jersey breeds had similar longevity up to 5 yr of age, both living longer than Holstein. Because raising replacement heifers is the second largest expense on a dairy operation after feeding costs for the milking herd, Jerseys and Brown Swiss would have an advantage over Holsteins. However, the Brown Swiss cows calved later for the first time, had fewer lactations initiated, and often had lowest proportions of DIM5 with respect to HL5. The difference between DIM5 and HL5 is the nonproductive dry period. Therefore, Brown Swiss did not offer fast returns. Nevertheless, a very high ratio of DIM5 over HL5 might suggest reproductive problems of the cow leading to extended lactations.

Jerseys performed best for number of lactations completed, followed by Holsteins. This comes from Jerseys' younger ages at first calving and shorter calving intervals (Garcia-Peniche et al., 2005). Most longevity studies adjust for age at first calving and remove any association between the 2 traits. However, low ages at first calving for Jerseys apparently give an official longevity evaluation advantage, because the difference between Jersey and Brown Swiss for productive life is about 3 mo (USDA, 2004), approximately the age at first calving difference between the 2 breeds. Age at first calving is a cause of longevity as measured in some traits such as herd-life, number of lactations, and length of productive life. Age at first calving does not influence days lived or stayabilities. It could be fitted as a classificatory variable, if there was interest in its outcomes. In the present study, age at first calving was not fitted to keep the models as simple and as homogeneous as possible across methods.

Foster (1988), using simulated data, found that the mean time from birth to payoff for an average cow was

Table 4. Risk ratios obtained using survival analysis for PTA classes of milk, productive life (pL), and SCS on farms with 2 breeds of cows.

Class ¹	Holstein-Brown Swiss herds			Holstein-Jersey herds		
	PTA milk	PTA pL	PTA scs	PTA milk	PTA pL	PTA scs
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

¹Classes were obtained by adding and subtracting half the standard deviation of PTA to the average PTA value; the cows inside this range were class 2. Class 1 included cows that were below that range; and class 3 cows with larger values.

60 mo, with a 15 mo range, depending mainly on age at calving. A study of costs per kilogram of milk produced per breed would be useful to verify which breeds recover rearing costs more rapidly.

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 with our findings of surviving relative to milk cPTA classes.

Censoring with predetermined time allowed per individual can be handled by the Survival Kit (Ducrocq and Solkner, 2000) for survival analysis. The Survival Kit was used to analyze TDIM, assuming the “failure rates” or times when cows stopped accumulating DIM can be modeled with the Weibull distribution. All the effects (called “covariates”) were considered time-independent. Thus, the differences between survival analysis and the other analyses in this study were that cows still alive when they reached 5 yr of age were considered censored, and the failure time, defined as the time to stop accumulating DIM, was assumed to follow a Weibull distribution in survival analysis. In this case, TDIM was a composite of various subtimes, the lactations. The survival analysis answers a different question than the cow’s survival behavior up to 5 yr of age, analyzed with the other models. Survival analysis was estimating the probable total survival. Because all the ρ parameters found were larger than 1, the risk of failure increased with time.

Many factors other than breed and region affect longevity, including herd size. Herd sizes for the 3 data files used were quite variable, and some breed differences could have resulted from differential management in small vs. large groups of animals of one breed or another. However, fitting herd size classes in the model did not modify the overall conclusions of this work about breed, region, and breed $\times$ region interaction effects. Herd size can change over time, potentially changing its effect on longevity traits. The present study suggests that herd size does not substantially affect breed and region influences on longevity traits.

CONCLUSIONS

In the different analyses, the Jersey breed showed an advantage for all the longevity-related traits studied. Brown Swiss survived well through 5 yr of age, but advanced age at first calving limited the value of some longevity traits to 5 yr of age for that breed. The survival of Holsteins to 5 yr of age was lower than for Brown Swiss or Jerseys, both in herds with single breeds and in herds with 2 breeds of cows. Breed $\times$ region interaction was always present and some analyses suggested that heat stress affected Holstein for longevity traits. Using herds with 2 breeds for direct comparisons did not yield advantages over using data from farms with 1 breed. Survival analysis appeared to use information more efficiently and is preferred for this type of trait related to longevity. It is also the method of choice in many countries for within-breed longevity evaluations.

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