

Mortality, Culling by Sixty Days in Milk, and Production Profiles in High- and Low-Survival Pennsylvania Herds

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ABSTRACT

The objectives were to describe culling patterns and reasons for culling across lactation, estimate mortality and the proportion of cows leaving from 21 d before an expected calving date through 60 d in milk (DIM; CULL60) for Pennsylvania (PA) dairy herds, and to describe production measures for herds with high and low mortality and CULL60. Weekly culling frequencies and reasons for culling from 3 wk before a reported expected calving date through ≥ 100 wk of lactation were calculated for all PA cows with at least 1 Dairy Herd Improvement test in 2005. It was estimated that at least 5.0% of PA dairy cows died in 2005, and that at least 7.6% were culled by 60 DIM. The majority of cows exiting the herd by 60 DIM either died (35.1%) or had a disposal code of injury/other (29.9%). A total of 137,951 test-day records from 20,864 cows in herds with high mortality ($>8.0\%$) and CULL60 ($>12.0\%$) and 136,906 test-day records from 12,993 cows in herds with low mortality ($<1.4\%$) and CULL60 ($<2.9\%$) were retained to describe differences among herds with high and low survival. Least squares means for weekly milk yield, fat and protein percentages, and somatic cell score (SCS) were estimated with a model that included fixed effects for herd environment (high or low survival) and week nested within herd environment and lactation; random effects were cow, herd-test-day, and error. Cows from herds with high mortality and CULL60 produced more milk in lactations 1 ($+1.9 \pm 0.15$ kg/d) and 2 ($+0.9 \pm 0.16$ kg/d), but less in lactations 4 (-0.7 ± 0.22 kg/d), 5 (-1.4 ± 0.29 kg/d), and ≥ 6 (-0.7 ± 0.32 kg/d) and had higher SCS ($+0.24 \pm 0.02$), more change in early-lactation fat percentage (-1.77% vs. -1.59%), and a greater frequency of fat-protein inversions ($3.6 \pm 0.3\%$). There is an opportunity to manipulate management practices to reduce mortality and early-lactation culling rates, which will improve cow welfare and the efficiency of dairy production by capturing a greater

proportion of potential lactation milk yield, increasing cow salvage values, and reducing replacement costs.

Key words: culling, mortality, lactation curve

INTRODUCTION

The average productive life of US Holsteins declined by 3.95 mo for cows born in 2000 compared with cows born in 1980 (AIPL, 2008), and there was a 7% decline in the proportion of cows surviving to 48 mo of age in cows that were included in the Northeast Sire Summaries (Cornell University Dairy Genetics, 2008). Greater herd culling rates result in greater replacement costs and if the decline in herd life was associated with deteriorating cow health, then the welfare of dairy cows may be compromised.

The genetic trends for survival have been favorable (AIPL, 2008; Cornell University Dairy Genetics, 2008), which indicates that declines in cow survival are due to shifts in herd management rather than genetic selection. Economic pressure has encouraged dairy producers to increase efficiency by implementing management changes. Many of these management changes (shifting from tie-stalls to free-stalls, feeding a TMR, and limiting pasture access) were associated with greater mortality rates (McConnel et al., 2008).

Recent herd life trends are more encouraging, with a productive life increase of 1.87 mo for cows born in 2004 compared with 2000 (AIPL, 2008). Much of the reversal in herd life trends was due to greater survival rates from first to second and from second to third lactation, but survival to fourth and later lactations has not improved (Hare et al., 2006). Selection for productive life (VanRaden and Wiggans, 1995) was partly responsible for the change in herd life trend. There have been large increases in the use of timed insemination programs since 1993 (Miller et al., 2007), which is likely responsible for some change in survival to second and third lactations because greater pregnancy rates were associated with longer survival (VanRaden et al., 2004; Norman et al., 2007). Fetrow et al. (2006) described culling as an economic decision by herd managers, which indicates that variation in culling rate among

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herds may not reflect differences in general cow health, but rather more aggressive replacement of economically inferior cows with superior young cows in high-cull-rate herds. For this reason, measures such as mortality rate may be a more accurate reflection of differences in cow health and well-being among herds than cull rate.

Healthy cows can be expected to rarely be culled in early lactation because of the production potential for the remainder of lactation. Thus, high early-lactation cull rates are likely an additional indicator of poor cow health. The probability of culling was greatest in early lactation (Fetrow et al., 2006). Variation across herds in mortality and early-lactation culling rates indicated that there is an opportunity to improve dairy cow health, which is of critical importance because of increased consumer focus on dairy cow welfare (NDAWB, 2008).

Differences in production patterns for herds with high and low early-lactation culling would indicate areas of herd management that can be manipulated to improve early-lactation cow health. Appuhamy et al. (2007) demonstrated that disease resulted in changes to lactation curves, and Rogers et al. (1989) demonstrated that survival was associated with the rate of maturity across lactations. Milk production characteristics within and across lactation for herds with low mortality and early-lactation culling could serve as benchmarks to identify areas for improved herd management, but have not been described for such herds to our knowledge. Likewise, SCS traits from low mortality and early-lactation culling herds would be useful benchmarks because mastitis increased the probability of mortality and culling (Gröhn et al., 1998; Bar et al., 2008). Milk component characteristics from low mortality and early-lactation culling herds would help identify herds with excessive negative energy balance in early lactation (de Vries and Veerkamp, 2000) and cows at risk of developing acidosis (Bramley et al., 2008).

The objectives were to describe culling patterns and reasons for culling across lactations, estimate mortality and early-lactation culling rates for Pennsylvania (PA) dairy herds, and to contrast production measures between herds with high or low mortality and early-lactation culling rates.

MATERIALS AND METHODS

Records from herds on DHI test in PA during 2005 were provided by Dairy Records Management Systems (Raleigh, NC). Records included test-day milk yield, test-day fat and protein percentage, and test-day SCS. Herd code, birth date, calving date, lactation number, and disposal codes were also available. Disposal codes included sold for feet and leg problems, sold for dairy purposes, sold for low production, sold for reproduc-

tion, sold for injury/other, died, sold for mastitis, sold for disease, sold for other udder problems, and sold for unknown reasons.

Herds with 95% or more Holsteins and with 6 or more test dates in 2005 were retained for analysis. Test-day records from cows that calved in 2004 or earlier and that were still lactating in 2005 were available; however, the herd statistics generated were specific to 2005, so only test-day records from 2005 were retained regardless of calving and dry-off dates. Likewise, only disposal codes recorded in 2005 were considered.

Annual herd turnover rate, annual culling rate, the annual rate of culling between 21 d before expected calving date and 60 DIM (CULL60), and annual mortality rate for all lactations, first lactation, second lactation, and \geq third lactation were calculated as recommended by Fetrow et al. (2006). The numerator was all cows leaving the herd in 2005 (herd turnover rate), all cows leaving except those sold for dairy purposes (culling rate), all cows that died (mortality rate), or all cows that left the herd 21 d before an expected calving date through 60 DIM (CULL60). The denominator was herd size, which was the average number of lactating plus nonlactating cows on test days during 2005. Culling rate and CULL60 included cows that died, which is reflective of how the term culling is used in the US dairy industry (Fetrow et al., 2006). Calculations were based on 2,539,982 test-day records from 2,574 herds that averaged 11.45 test dates during 2005.

It was assumed that cows sold within 3 wk of an expected calving date left for reasons related to health events associated with an impending calving. Thus, culling records for cows that were culled within 3 wk of an expected calving date were associated with the lactation corresponding to the expected calving. The exceptions were cows sold for dairy purposes or for reproduction. Cows sold for dairy purposes were removed from calculations of CULL60 because there was no indication that such cows were in poor health. Cows assigned an expected calving date and subsequently sold for reproduction were likely assumed pregnant during lactation, but diagnosed nonpregnant at or near dry-off. Culling records for those cows remained associated with the recorded lactation.

Week of lactation when culled or died was determined for all cows that left the herd for reasons other than dairy purposes. The percentage of total culls that occurred in each week of lactation was described separately for lactations 1, 2, and ≥ 3 . The proportion of culls and mortality that occurred during the transition period (21 d before an expected calving date through 21 DIM) was calculated separately by month of calving to determine seasonal culling patterns and mortality rates.

Table 1. Mean (%) and SD of herd turnover characteristics for 2,574 Pennsylvania herds

Characteristic	Mean	SD
Herd turnover rate	30.7	12.7
Culling rate ¹	27.7	11.1
Reporting herd mortality rate ²	5.6	4.2
All herd mortality rate ³	4.6	4.4
Culling by 60 DIM	6.8	4.6
Lactation 1 cull rate	17.7	14.9
Lactation 2 cull rate	27.0	18.7
Lactation ≥ 3 cull rate	46.0	21.8
Lactation 1 mortality rate	2.0	4.0
Lactation 2 mortality rate	3.5	5.8
Lactation ≥ 3 mortality rate	7.8	8.5
Proportion of aged cows ⁴	10.7	6.6
Total culls (%)		
Sold for injury/other	26.3	23.8
Sold for reproduction	20.1	16.5
Died	16.5	14.5
Sold for mastitis	14.1	13.6
Sold for low production	7.1	10.8
Sold for feet and legs	6.9	9.3
Sold for disease	4.1	9.3
Sold for other udder problem	2.6	6.3
Sold with reason unknown	2.2	9.8

¹Herd turnover rate minus cows sold for dairy purposes.

²Mortality rate only for 2,107 herds with at least 1 reported cow death.

³Mortality rate for all herds including herds with no reported cow deaths.

⁴Cows with ≥ 5 lactations and ≥ 6 yr of age.

Test-day records from high and low survival herds were retained for further analysis to describe differences contributing to survival. Mortality and CULL60 rates were influenced by the proportion of older cows, so weighted averages for mortality and CULL60 were calculated by applying an equal weight to first, second and \geq third lactation to avoid bias by the herd's average age when selecting herds that represent high and low survival environments. Herds that were in the lowest 25% for both weighted average mortality ($<1.4\%$) and weighted average CULL60 ($<2.9\%$) were selected to represent high survival environments. The high survival herds were associated with 136,906 test-day records. To create a low survival data set with approximately the same number of test-day records, herds with weighted average mortality and CULL60 of $>8.0\%$ (84th percentile) and $>12.0\%$ (88th percentile), respectively, were selected (137,951 test-day records). More herds were included in the high survival subset (316) than the low survival subset (156) because the high survival herds were smaller than low survival herds. There were more cows in the low survival herds (20,864) because of greater herd turnover rates than in the high survival herds (12,993).

The proportion of nondairy culls occurring by week of lactation was calculated for high and low survival

herds. Production measures were estimated within and across lactations for both groups. Least squares means for test-day milk yield, fat percentage, protein percentage, SCS, and MUN were estimated with mixed models in ASREML (Gilmour et al., 2006). Fat-protein inversions, or test-day records with a fat percentage that was lower than protein percentage (**INVERT**), were analyzed. Test-day records were assigned a 1 if protein percentage was greater than fat percentage and 0 otherwise. The basic model to analyze all traits was

$$y_{ijklm} = HE_i + \text{week}_j(HE_i \times P_k) + \text{htd}_l + \text{cow}_m + \varepsilon_{ijklm}, \quad [1]$$

where y = test-day milk yield, fat percentage, protein percentage, SCS, or INVERT; HE = herd environment i (high or low survival); week = week of lactation j (52 levels for week after calving), which was nested within herd environment i by parity k ($HE_i \times P_k$); htd = the random effect of herd-test-date l ; cow = the random effect of cow m , and ε = random error. There were 3 levels for parity (1, 2, and ≥ 3) and 2 levels for herd environment (high or low survival), resulting in 6 levels for $HE_i \times P_k$. Fat-protein inversions were analyzed as a binary trait with a GLM model that invoked a logit link function (Gilmour et al., 2006).

Test-day records were analyzed with the following model that did not consider an interaction between lactation and week:

$$y_{ijklm} = HE_i + \text{week}_j(HE_i) + \text{lact}_k(HE_i) + \text{htd}_l + \text{cow}_m + \varepsilon_{ijklm}, \quad [2]$$

where week j is nested within herd environment i (HE_i), and lactation number k (lact_k with 6 levels corresponding to lactation 1, 2, 3, 4, 5 and ≥ 6) nested within HE_i . All other effects were as described for model 1. The purpose of the second model was to more fully describe changes for cows with more than 3 calvings.

RESULTS AND DISCUSSION

Culling and Survival Rates

Culling and mortality statistics for 2005 are reported in Table 1 for 2,574 herds, and the culling distribution by disposal code and week of lactation is depicted in Figure 1. The average herd turnover rate was 30.7%. Three percent of cows that were sold for dairy purposes were removed from the culling data set, resulting in an average herd culling rate of 27.7%. The standard deviation for herd culling rate was 11.1%, indicating that there were significant differences in culling rates

among herds. Culling rates were lowest for first lactation (17.7%) and greatest for third and higher lactations (46%). The most common reason indicated for cow disposal was injury/other, followed by reproduction, mortality, and mastitis (Table 1). The culling distribution depicted in Figure 1 is similar to that reported for herds in Minnesota (Fetrow et al., 2006), except that culling that occurred within 3 wk before a reported expected calving date was associated with the subsequent lactation in the current study instead of the end of the previous lactation. In total, 3.2% of culls occurred before calving, 5.5% occurred during the first week of calving, and 26.2% occurred from 21 d before an expected calving date though 60 DIM.

Culling distributions by lactation 1, 2, or ≥ 3 are in Figure 2 for the first 25 wk of lactation. The percentage of second-lactation culls that occurred during the first week of lactation was 4.0%, whereas 7.0% of third and higher lactation cows were culled in the first week of lactation. Week 1 culling rates were lowest for first lactation (2.8%), but were underestimated because of incomplete data recording for first calf heifers that left the herd before they began DHI testing.

The unfavorable effect of calving on cow survival was more pronounced during the hottest calving months (Figure 3). The period spanning 3 wk before and 3 wk after calving has been termed the transition period and is a critical period for cow survival and to establish a

successful lactation (Drackley, 1999). The proportion of culling that occurred during the transition period varied by month of calving. Less than 15% of culled cows calving in fall through early spring left within 21 DIM, whereas >15% of culls occurred within 21 DIM for cows that calved from July through September. The proportion of nondairy cow disposals due to mortality followed a similar seasonal trend.

Ideally, culling would rarely occur in early lactation because little or none of a cow's potential milk production for the lactation would be realized despite high costs incurred during the rearing period for heifers or dry period for later lactations. Additionally, salvage values are likely reduced in the case of injury or compromised health and no salvage value would be obtained in the event of death. Fetrow et al. (2006) described culling that replaced one cow with a more economically efficient cow as an economic cull, whereas cows that are sterile, irreparably injured, or that die are forced or biological culls. Cows that die or are culled by 60 DIM are primarily forced culls, and the proportion of biological culling in the current study was greater than previous estimates. Van Vleck and Norman (1972) reported cow disposal reasons for 188 Holstein herds from 1961 through 1969. The disposal codes analyzed were developed from producer descriptions, and changes in culling practices were evident across time. In the current study, 7.1% of disposals occurred for low produc-

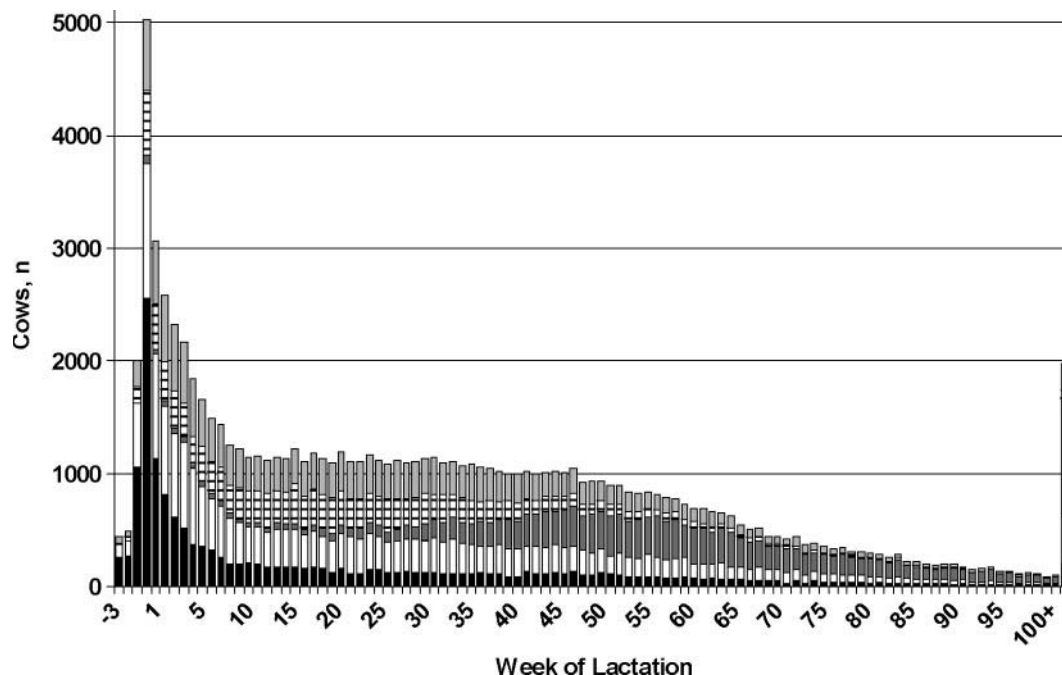


Figure 1. Total number of cows (n) that died (black), or were culled with codes corresponding to injury/other (white), reproduction (dark gray), mastitis (horizontal lines), and all other reasons (light gray) by week of lactation. Color figure is available online (<http://jds.fass.org/content/vol91/issue12/>).

tion, compared with 32.5% in Van Vleck and Norman (1972). In the earlier study, 7.7% of cows were culled for inability or disease and 4.0% were culled for other reasons, which included injury and cows that died with no other reason given. The total of those categories (11.7%) was less than the proportion that died (16.5%) in the current study. In a more recent study, Norman et al. (2007) reported the relative emphasis placed on yield and fitness traits when making culling decisions for cows calving between 1982 and 2000. Longer surviving cows had greater first-lactation yield for all years studied, but the effects of fertility and SCS on survival increased relative to yield across time. Those observations support Weigel et al. (2003), who reported that the relative risk of culling for high-producing cows in 1996 through 2000 had increased when compared with high-producing cows in 1981 through 1989.

Aged cows were considered those that were ≥ 6 yr of age and in their fifth or higher lactation. The restriction for lactation number was required to eliminate older cows that were not productive due to factors such as late age at first calving and infertility. The percentage of aged cows in the average herd was $10.7 \pm 6.6\%$. The proportion of aged cows was comparable to the percentage of Holstein cows born in 1997 that survived to lactation 5 (14.3%), which declined steadily from 24.2% in 1980 (Hare et al., 2006).

Mortality and Culling by 60 DIM

The most common disposal code chosen for cows exiting during the transition period was mortality (44.6%). An additional 27.4% left for injury/other during the transition period. Hadley et al. (2006) reported that 42% of mortality occurred in the first 60 DIM. The percentage of mortality occurring in this study from 0 to 60 d was 42%, but the proportion occurring from 21 d before an expected calving date through 60 DIM was 52%. As lactation progressed, reproduction became a more common reason for disposal and the proportion of cows that died or were injured declined. The disposal codes indicate that most cows culled by 60 DIM had compromised health or were injured.

Among herds that reported at least 1 case of mortality (2,107 herds), the average annual herd mortality rate was 5.6% (Table 1). If herds that do not report mortality are assumed to have true 0% mortality rates, the average annual herd mortality rate was 4.6%. On the average farm, 6.8% of cows were culled by 60 DIM annually. The majority of cow deaths occur in early lactation (Figure 1), so there was a positive correlation ($r = 0.50$) between mortality rate and CULL60. Herds that reported no mortality had an average CULL60 of 3.7%, compared with 7.5% among herds that had ≥ 1

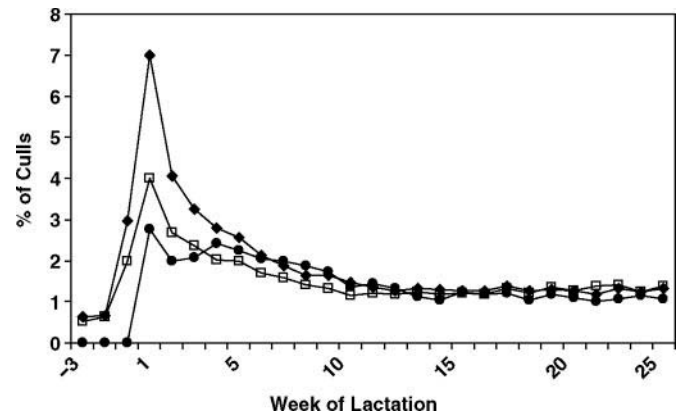


Figure 2. Percentage of total culls in first (●), second (□) and \geq third (◆) lactations that occurred per week for the first 25 wk of lactation.

mortality incident reported. Most herds reporting no mortality (85.4%) had a CULL60 that was less than 7.5%. This likely indicated that a large proportion of herds with no reported mortality had true 0% mortality rates and that excluding those herds would result in overestimated herd mortality rates. The lactation mortality rates for lactation groups 1, 2, and ≥ 3 reported in Table 1 assume that herds with no reported mortality had true 0% mortality rates. Mortality rates (7.8%) were greatest for lactation ≥ 3 and lowest for lactation 1 (2.0%).

First-lactation mortality and CULL60 are underreported because heifers that die before they reach a test-day in first lactation may not be in the DHI system and, therefore, are not reported as having been culled. Not all herds failed to report first-lactation culling that occurs before first DHI test. Fifty herds with 100 or more first-lactation cows that recorded at least 1 incidence of culling before the first test-day in first lactation were

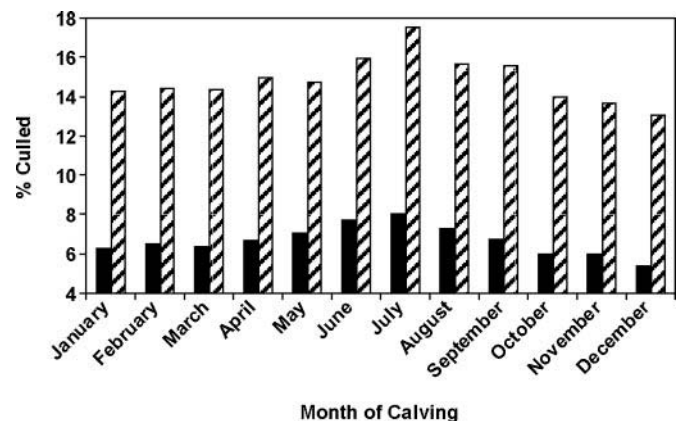


Figure 3. Percentage of culled cows coded as died (solid) or culled during the transition period (hatched) by month of calving.

Table 2. Mean rates of culling by 60 DIM (CULL60) and mortality rate for 50 large herds when first-lactation cow removals occurring before first test-day were included or excluded compared with 35 large cohort herds that did not report first-lactation cow removals before first test-day

Item	Included	Excluded	Cohorts
All lactation CULL60 (%)	9.9	8.7	7.1
Lactation 1 CULL60 (%)	4.8	1.4	1.5
All lactation mortality rate (%)	6.2	5.6	5.9
Lactation 1 mortality rate (%)	3.3	1.8	2.3

compared with 35 herds with 100 or more first-lactation cows and with no recorded incidences of culling before first test-day to determine the extent of underreported mortality and CULL60 for first-lactation cows (Table 2). Lactation 1 CULL60 was 4.8% for herds that reported culling before first test-day, compared with 1.5% for herds that did not report those culls. Culls that occurred before first DHI test were removed for the herds with complete data recording to determine the effect that not recording such culls had on overall mortality and CULL60. First-lactation mortality (1.8%) and CULL60 (1.4%) after excluding those animals were similar in magnitude to the observed rates for the 35 herds with incomplete recording.

Only 492 out of 2,574 herds (19%) reported 1 or more first-lactation culls before first DHI test. Of those herds not reporting first-lactation culls before first DHI test, the average second and third lactation CULL60 were 4.6 and 12.2%, respectively. The proportion of cows culled by 60 DIM in second lactation (6.0%) and third lactation (15.7%) were greater for those herds that did report culling before first DHI test. This indicates that many herds not reporting culls before the first DHI test likely have excellent cow health during the transition period and simply had no culls to report. Nevertheless, total herd mortality rates and CULL60 are underestimated due to incomplete first-lactation recording.

Average mortality rate and CULL60 increased with herd size. Herds were grouped into those with ≤ 100 cows (2,116 herds), 101 to 250 cows (364 herds), 251 to 500 cows (62 herds), and >500 cows (32 herds). Average mortality rates were 4.4, 5.2, 5.8, and 6.0% as herds went from the smallest herd-size group to the largest. Rates of CULL60 were 6.4% for herds with ≤ 100 cows, 8.4% for herds with 101 to 250 cows, 8.7% for herds of 251 to 500 cows, and 9.0% for herds of >500 . The relationship between larger herd size and greater mortality rates was described previously (Smith et al., 2000; Hadley et al., 2006; McConnel et al., 2008).

The total proportion of cows that died or that were culled by 60 DIM was greater than indicated by average herd culling and mortality rates because of the association of mortality and herd size. Mortality and

CULL60 were weighted by herd size to determine the total proportion of cows that died (5.0%) or were culled by 60 DIM (7.6%). However, those estimates are biased downward because of incomplete recording for first-lactation culls.

High and Low Survival Herds

Characteristics of herds with high and low early-lactation survival are reported in Table 3. Although culling rate was not directly used to select high and low survival herds, the annual culling rate for the low survival herds was 2.15 times greater than for high survival herds. This allowed herds with high survival to sell more animals for dairy purposes (3.7 vs. 2.6%). For the high survival herds, first and second lactations had negligible mortality and CULL60, and rates for \geq third lactation were less than observed for first-lactation cows in the low survival herds. Mortality (24%) and CULL60 (30%) in \geq third lactation for low survival herds were very high. Culling distributions for high and low survival herds are displayed in Figure 4. Culling for any specific week was 2.1% or less for high survival herds, but 7.7% of culling occurred in wk 1 alone for low survival herds. The differences in culling rates between high and low survival herds was more striking when the greater proportion of aged cows in the high (14.1%) versus low (8.5%) survival herds are considered because of the greater risk for mortality or early culling in later lactation cows. The culling distribution presented in Figures 1 and 4 suggests that transition cow management is very meager in many dairy herds, but Figure 4 clearly indicates that high levels of cow health through the transition period are attainable.

Milk Production for High and Low Survival Herds

Average milk production levels were similar between the high and low survival herds (Table 3). Nevertheless, patterns of production within and across lactations were different. Figure 5 presents milk yield least squares means for cows in lactation 1 through ≥ 6 . Rogers et al. (1989) reported that a greater change in milk production from first to later lactations was associated with longer survival, and speculated that improved cow health allowed yield to increase across lactations. Results from the current study support that observation. Low survival herds had relatively high production in first and second lactation; maximum milk yield was achieved in third lactation, which was not significantly different than yield in lactation 4. An apparent decline in cow health for later lactations resulted in lower levels of milk production, and milk yield in lactations 5 and 6 were significantly lower than lactation 2. Milk yield

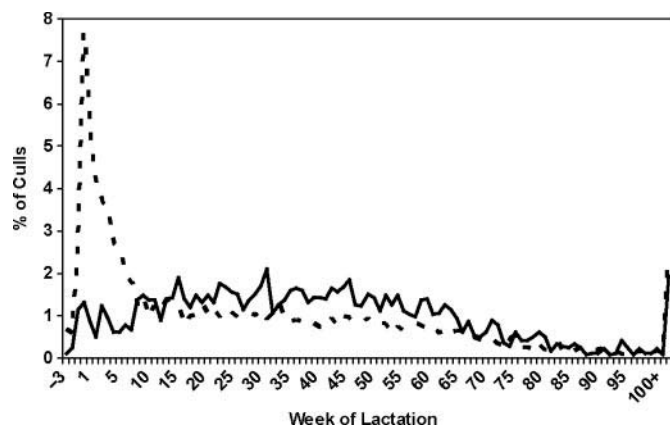


Figure 4. Percentage of total culls for herds with high (solid) and low (dashed) survival environments that occurred per week.

was greater in lactation 4 than lactation 3 ($P = 0.001$) and tended to be greater than lactation 5 ($P = 0.06$) for high survival herds. Lactation 2 milk yield was lower ($P < 0.03$) than fifth and \geq sixth lactation yield for high survival herds.

Lactation curves for high and low survival herds are displayed in Figure 6. For the high survival herds, peak yield was achieved 4, 2, and 4 wk earlier than low survival herds for lactation groups 1, 2, and ≥ 3 , respectively. The less pronounced and later peaks likely indicated more disease in the low survival herds. Apuhamy et al. (2007) demonstrated that cows with early-lactation metabolic disease had lower and later

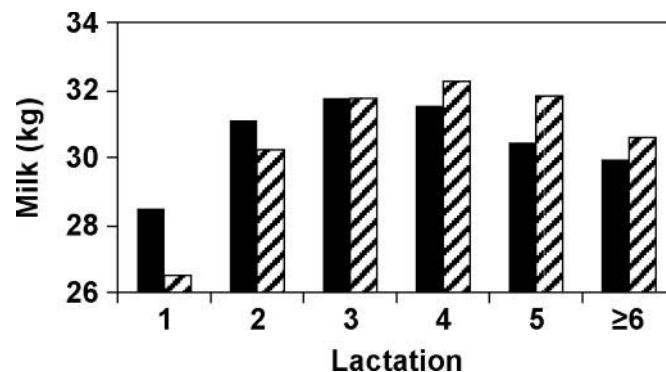


Figure 5. Predicted daily milk yield of cows from herds with high (hatched) and low (solid) survival environments by lactation.

peaks than nondiseased cows. First-lactation cows had greater milk production than later lactations beginning in wk 31 for low survival herds. Because of relatively greater production in mature cows, that transition was not observed for an additional 7 wk in high survival herds.

Peak production in \geq third lactation was 1.05 kg greater than that in second lactation for low survival herds, but 2.93 kg greater for high survival herds. The ratio of peak yield in lactation 1 to peak yield lactation ≥ 3 (**PYR**) was 0.73 in high survival herds and 0.80 in the low survival herds (Table 3). Likewise, the ratio of average daily milk yield across first lactation to average daily milk yield across \geq third lactation (**MYR**) was lower in high survival herds than low survival herds (0.80

Table 3. Mean, minimum, and maximum characteristics for herds with high and low survival environments

Herd characteristic	High survival ¹			Low survival ²		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Cows (n)	53.61	12.67	546.83	110.06	15.36	1,379.83
Cull rate (%)	19.49	1.20	136.99	42.82	19.29	181.30
Mortality rate (%)	0.34	0.00	3.76	12.94	4.49	54.30
CULL60 ³ (%)	1.30	0.00	5.06	15.22	6.95	32.58
Lactation 1 mortality rate (%)	0.06	0.00	3.82	5.63	0.00	44.44
Lactation 1 CULL60 ³ (%)	0.21	0.00	8.05	5.91	0.00	47.37
Lactation 2 mortality rate (%)	0.01	0.00	1.57	11.78	0.00	69.42
Lactation 2 CULL60 ³ (%)	0.20	0.00	7.89	13.09	0.00	56.41
Lactation ≥ 3 mortality rate (%)	0.59	0.00	4.24	23.98	0.00	105.26
Lactation ≥ 3 CULL60 ³ (%)	2.47	0.00	8.78	29.98	5.70	69.23
Age at first calving (mo)	26.17	22.65	44.08	27.23	23.05	34.56
Mean milk yield (kg/d)	30.48	15.75	40.60	30.17	17.22	44.38
Lactation 1 peak yield ratio ⁴	0.73	0.55	0.92	0.80	0.66	1.01
Proportion of aged cows ⁵ (%)	14.06	0.00	59.31	8.47	0.00	36.51
First-service conception rate (%)	33.81	0.00	100.00	30.54	0.00	100.00
Days to first service	94.50	58.31	158.00	95.85	60.93	176.66

¹316 herds with $<1.4\%$ mortality and $<2.9\%$ of cows culled by 60 DIM.

²156 herds with $>8.0\%$ mortality and $>12.0\%$ of cows culled by 60 DIM.

³CULL60 = the proportion of cows culled from 21 d before an expected calving date through 60 DIM.

⁴Average first-lactation peak milk yield/ ≥ 3 lactation peak milk yield.

⁵Cows with ≥ 5 lactations and ≥ 6 yr of age.

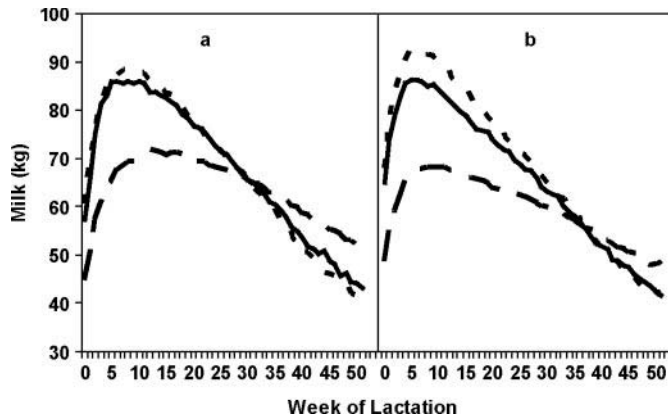


Figure 6. Predicted milk yield of first (---), second (—), and third or later (...) lactation cows from herds with low (a) and high (b) survival environments by week of lactation.

vs. 0.87, respectively). Greater MYR and PYR were associated with lower survival across all 2,574 herds. The correlation between MYR and CULL60 was $r = 0.20$, whereas the correlation between MYR and mortality rate was $r = 0.28$ ($P < 0.001$). The correlation of PYR with CULL60 ($r = 0.17$) and with mortality rate ($r = 0.18$) was highly significant. On the other hand, the correlation of average first-lactation milk yield with CULL60 and mortality rate was not significant. High first-lactation milk yield was not associated with inferior cow health, but high MYR or PYR would appear as indicators of inferior mature cow health rather than exceptional performance by first-lactation cows.

Milk Components in High and Low Survival Herds

Least squares means for fat percentage across lactation was 3.77 and 3.73% for high and low survival herds, whereas protein percentage was 3.08 and 3.11%

across lactation for high and low survival herds, respectively. Although average fat percentage was similar across lactation, differences were more pronounced for early lactation. Least squares means for wk 1 and nadir fat percentage by lactation group are in Table 4. Low survival herds had greater fat percentages in wk 1 and a lower nadir fat percentage, which resulted in greater changes in fat percentage from wk 1 to nadir. The greater decline in early-lactation fat percentage indicates that cows in low survival herds had more severe negative energy balance than cows in high survival herds. de Vries and Veerkamp (2000) stratified cows into quartiles based on change in fat percentage. Cows with the greatest decline in fat percentage had the most severe negative energy balance. The average week when nadir fat percentage was reached was 1, 4, and 3 wk longer in low versus high survival herds for lactations 1, 2 and ≥ 3 , respectively, indicating that negative energy balance was prolonged in low survival herds.

Although fat percentage was greater in low survival herds during early lactation, those herds had a greater proportion of fat-protein inversions (Table 4). The odds ratio of fat-protein inversions in low survival herds to high survival herds was 1.64:1 ($P < 0.001$). A low fat percentage relative to protein percentage indicated that a cow may be acidotic and is associated with more energy-dense diets (Bramley et al., 2008). This may indicate a potential conflict between increasing milk yield though diet energy manipulation and the development of an unfavorable environment for the health of cows.

Average SCS in first, second, and \geq third lactations in high and low survival herds are in Figure 7. Somatic cell score was lower in high survival herds for all lactations, indicating that the high survival herds had better udder health. Least squares means for SCS across lactation were 2.86 in high survival herds versus 3.10 in low survival herds. The association between SCS

Table 4. Least squares means of fat and protein percentage across lactation, fat percentage in wk 1, nadir fat percentage, change in fat percentage from wk 1 to nadir (Δ fat %), weeks at nadir fat percentage, and the percentage of fat-protein inversions in lactations 1, 2, and ≥ 3 for cows from herds with high or low survival environments

Item	High survival ¹			Low survival ²		
	1	2	≥ 3	1	2	≥ 3
Fat %	3.79	3.78	3.75	3.74	3.73	3.71
Protein %	3.07	3.12	3.05	3.10	3.14	3.08
Wk 1 fat %	4.96	4.98	5.12	5.25	5.11	5.23
Nadir fat %	3.48	3.43	3.44	3.44	3.40	3.40
Δ Fat %	1.48	1.55	1.68	1.81	1.71	1.83
Weeks at nadir fat %	13	10	12	14	14	15
Fat-protein inversions %	5.05	6.32	6.49	7.96	10.40	10.17

¹316 herds with $<1.4\%$ mortality and $<2.9\%$ of cows culled by 60 DIM.

²156 herds with $>8.0\%$ mortality and $>12.0\%$ of cows culled by 60 DIM.

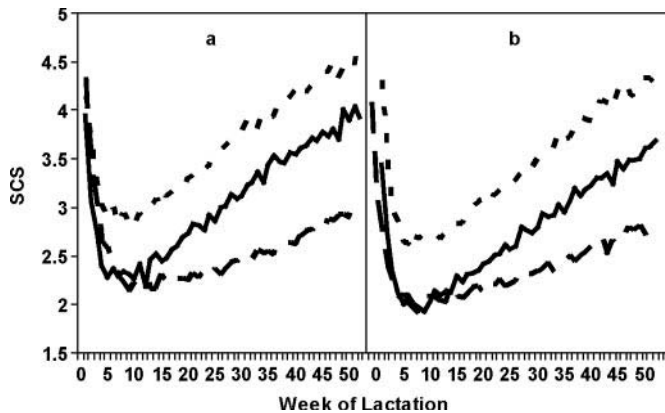


Figure 7. Predicted SCS for first (---), second (—), and third or later (...) lactation cows from herds with low (a) and high (b) survival environments by week of lactation.

and survival was not surprising because high levels of mastitis increased mortality and culling (Gröhn et al., 1998; Bar et al., 2008).

Although there were significant differences among high and low survival herds for milk yield profiles, fat percentage profiles, the proportion of fat-protein inversions, and SCS, the averages observed in the low survival herds may not indicate herd health problems in general. Table 3 indicates that there was significant overlap among high and low survival herds for most production measures that were examined. Negative energy balance, as indicated by change in early-lactation fat percentage, may have contributed to inferior cow health in a proportion of low survival herds; however, the average fat percentage in Table 4 reflects herds in which negative energy balance was not a concern, but that had other health problems such as a high SCS. Thus, the average trait values for low survival herds presented here should be viewed as areas for further exploration in herds with inferior cow health or mortality and not as benchmarks that directly identify the cause of inferior cow health. The trait values presented for high survival herds would indicate levels that can be considered adequate and are more directly applicable toward benchmarking than the low survival values.

CONCLUSIONS

The mortality rate of PA cows in 2005 was estimated >5%, whereas at least 7.6% of cows were culled between 21 d before an expected calving date and 60 DIM. The greatest rates of culling occurred near parturition in all lactations, and cows that left the herd in early lactation were more likely to have died or been injured than cows exiting the herd later in lactation. Nonetheless, many herds had low early-lactation culling rates and

there was large variation in herd culling patterns. Cows from herds with high mortality and CULL60 produced relatively more milk in first and second lactations and relatively less milk in fourth and later lactations than cows from herds with low mortality and CULL60. Cows from low survival environments had greater changes in early-lactation fat percentage, greater rates of fat-protein inversions, and higher SCS. This study indicates that there is an opportunity to manipulate management practices to reduce mortality and early-lactation culling rates. In addition to improving cow welfare, reducing mortality and early-lactation culling would improve the efficiency of dairy production by capturing a greater proportion of potential lactation milk yield, increasing cow salvage values, and reducing replacement costs.

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