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Selection on Yield and Fitness Traits When Culling Holsteins During the First Three Lactations

H. D. Norman,*[1] J. L. Hutchison,* J. R. Wright,* M. T. Kuhn,* and T. J. Lawlor†
*Animal Improvement Programs Laboratory, Agricultural Research Service, USDA, Beltsville, MD 20705-2350
†Holstein Association USA, Inc., Brattleboro, VT 05301

ABSTRACT

Emphasis by dairy producers on various yield and fitness traits when culling cows was documented for US Holstein calvings since 1982. Least squares differences between cows retained for additional parities and those culled were estimated for milk, fat, and protein yields; somatic cell score (SCS); days open (DO); dystocia score (DS), final score (FS), and 14 type traits. Compared with cows culled during first lactation, superiority for first-parity milk yield was 569 to 1,175 kg for cows with 2 lactations, 642 to 1,283 kg for cows with ≥2 lactations, 710 to 1,350 kg for cows with 3 lactations, and 663 to 1,331 kg for cows with ≥4 lactations. Cows retained for ≥2 lactations had first-parity SCS that were 0.34 to 0.62 lower (more favorable) than those of cows culled during first lactation; first-parity SCS for cows retained for 3 or ≥4 lactations were even more favorable than those of cows with 1 or 2 lactations. The negative genetic relationship between yield and fertility contributed to increased DO as selection for higher milk yield persisted across time despite considerable preference for early conception when culling cows. In 1982, cows retained in the herd for 2, 3, and ≥4 lactations conceived earlier during first lactation (19, 17, and 23 fewer DO, respectively) than those culled during first lactation; those differences had increased to 34, 41, and 52 fewer DO by 2000. Although DS has a negative relationship with survival, first-parity DS were only slightly lower (by 0.10 to 0.14) for survivors than for cows culled during first lactation. Cows retained for ≥2 lactations had greater first-parity FS by 1.4 to 1.9 points than those culled during first lactation. On a standardized basis, the most intense selection during first lactation was for milk and protein yields with less for fat (74 to 86% of that for milk), DO (18 to 74%), FS (22 to 38%), SCS (19 to 37%), and DS (7 to 15%). Producers continued to emphasize the same traits when culling during second and third lactations. Trait priority by producers during culling could aid in setting trait emphasis when selecting bulls for progeny test and could also be useful in developing software for index-based culling guides.
Key words: culling, fitness trait, yield trait, selection

INTRODUCTION

Genetic evaluations of dairy cattle have been a highly effective tool over the last 4 decades to aid in improving the ability of the US dairy population to produce large volumes of milk and milk components (Animal Improvement Programs Laboratory, 2006a). However, lack of evaluations for several fitness traits, some of which affect a cow's ability to function in a trouble-free manner, has limited the opportunity to improve those traits. Genetic evaluations for SCS (Schutz, 1994b) and productive life (VanRaden and Wiggans, 1995) were implemented in 1994 in the United States.

Using milk yields from 1960 to 1973, Keown et al. (1976) documented the amount of bias in sire evaluations if later-parity records of a daughter were included in the evaluation when her first-parity record was not available. That bias is a reflection of the extent of selection by producers when culling cows.

Traits excluded from breeding goals generally do not change much, except for those traits with a moderate to high genetic correlation with other included traits. Unfortunately, a few traits with an unfavorable relationship with milk and component yields have deteriorated over the same 4 decades (Dematawewa and Berger, 1998). An obvious example is cow fertility: the US Holstein mean for pregnancy rate decreased from 30.8% for cows born in 1960 to 21.2% for cows born in 2000 (Animal Improvement Programs Laboratory, 2006a), which is equivalent to an increase of 38.2 d open (**DO**) or almost 1 d/yr based on a 4-d increase in DO for each decrease of 1% in pregnancy rate (VanRaden et al., 2004). During those 40 yr, 43% of the decline (4.1% for pregnancy rate, 16.4 DO) was attributable to genetics (Animal Improvement Programs Laboratory, 2006a). Today, many cows with high yield experience negative energy balance near peak lactation, and more fail to conceive after first service than in the past (Faust et al., 1988; Washburn et al., 2002). Also, before genetic

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[1]Corresponding author: dnorman@aipl.arsusda.gov

evaluations became available for SCS (Schutz, 1994b), increasing milk yield was contributing to a small rise in clinical and subclinical mastitis (Emanuelson et al., 1988) because of unfavorable genetic correlations.

More traits are emphasized in dairy breeding programs as more data become accessible in national databases. VanRaden (2004) summarized breeding indexes that have been available in the United States since 1971 along with indexes used in 12 other dairy countries. The current primary USDA economic index is lifetime net merit (**LNM**), which has been revised frequently (VanRaden, 2004) to add new traits and to address changes in economics and in genetic correlations between traits (Tsuruta et al., 2004). The current LNM includes fat and protein yields, SCS, productive life, conformation, daughter pregnancy rate as well as service sire and maternal calving ease and stillbirth (VanRaden and Multi-State Project S-1008, 2006). Two additional indexes are provided by USDA based on pricing for fluid milk and for cheese yield; the fluid merit and cheese merit indexes value milk yield in opposite directions and include all the other traits in LNM as well.

Generally, as genetic evaluations are implemented for additional traits, the new traits are incorporated into a country's breeding index. Information on more fitness traits is becoming available through bull and cow evaluations from a growing number of exporting countries, often through the International Bull Evaluation Service (2005). Selection on those traits may be direct because of their inclusion in the breeding index or indirect because of their relationships to other included traits.

Assigning economic weights to traits in a breeding index is complex because of the difficulty in 1) obtaining sound economic information on benefits and costs associated with most traits and 2) accurately estimating phenotypic and genetic relationships between all traits. Knowledge of which traits are important to dairy producers when culling cows might aid in determining the trait emphases that AI organizations should consider when choosing young bulls and graduating progeny-test bulls into active AI service. Failure to emphasize the same traits for selecting bulls as for culling cows could result in genetic gains that are less than optimal and obtained at a higher cost than necessary. Synchronization of trait emphasis by producers and AI organizations should result in more efficient genetic improvement than if selection emphases differ substantially.

Information on trait emphases that dairy producers use when culling could be incorporated into culling-decision software provided by DHI to simplify producer management decisions and thereby increase labor efficiency on the farm. Most dairy producers likely make culling decisions without reviewing all performance traits for each cow in the potential culling pool. An index-style culling guide that incorporates preferred trait emphases for culling would be useful, especially if producers were provided with the flexibility to modify assigned weights. Software that was based on overall economics could replace current culling strategies that often consider only 1 or 2 independent culling levels (Lehenbauer and Oltjen, 1998).

Objectives of this research were to determine 1) emphases currently placed on different yield and fitness traits when culling during each of the first 3 lactations, and 2) trends in trait emphases since 1982 as milk pricing and operating costs have changed.

MATERIALS AND METHODS

Data were yield (milk, fat, and protein), SCS, DO, and dystocia score (**DS**) records in the national lactation database at the Animal Improvement Programs Laboratory, USDA (Beltsville, MD), and type trait [final score, stature, strength, body depth, dairy form, rump angle, thurl width, rear legs (side view), foot angle, fore udder attachment, rear udder height, rear udder width, udder cleft, udder depth, and front teat placement] records from the Holstein Association USA (Brattleboro, VT) database. Protein yields began to be reported as true rather than crude protein in May 2000. Earlier CP yields had been converted to estimates of true protein yield by subtracting 0.0019 times the milk yield from the CP yield (VanRaden and Powell, 2000) and are referred to as true protein in this study. Records for cows that first calved between January 1982 and October 2000 were used to assess the emphasis that producers place on those traits when culling dairy cows in DHI herds. Only records from first parities before October 2000 were included to allow time for cows to complete at least 4 lactations; records from cows that changed herds during their first 4 lactations were excluded even though some bias could result if better cows were sold. To ensure that an additional record would be included if a cow survived and was retained in the herd, cows were required to be from herds that remained on test for 1,600 d after the first calving date of the cow. Herds were considered to be on continuous test until they had a 3-mo lapse without test-day data for any cow. Only records from cows with an identified sire were included. Records were excluded if a cow's first calving age was <15 or >36 mo. Calving intervals, which were used to verify DO, were derived from adjacent calving dates and were restricted to 270 to 650 d to minimize the number of missing parities. Yield records without protein information were excluded.

Analysis models were similar to the model used by Keown et al. (1976). Yield records from the USDA database had been standardized for calving age, calving month, milking frequency, lactation length, and previous DO (Schutz, 1994a); SCS records had been standardized for calving age, calving month, and lactation length (Schutz et al., 1995). The model to determine selection intensity for yield traits and SCS was:

$$Y1_{ijk\ell} = H_{ij} + S_k + e_{ijk\ell} \quad [1]$$

where $Y1_{ijk\ell}$ = first-parity yield (milk, fat, or true protein) or SCS for cow ℓ that calved in season j in herd i and belonged to survival group k; H = effect of herd-calving season (January–March, April–June, July–September, and October–December); S = effect of survival group based on number of parities in the herd, and e = effect of random error. Survival groups were defined to examine whether cows with the best performance during early parities were those that survived the longest: S_1 (cow had only a first-parity record), S_2 (cow had only first- and second-parity records), S_3 (cow had only first-, second-, and third-parity records), and S_{4+} (cow had ≥4 records). Each analysis was repeated using only survival groups S_1 and S_{2+} (cow had ≥2 records). All analyses were repeated for each year of first calving from 1982 through 2000.

Because records for DO and DS in the USDA national database are not standardized for calving age and season, 2 additional effects were added to model [1] to estimate selection intensity for DO and DS:

$$Y1_{ijk\ell mn} = A1_m + C_n + H_{ij} + S_k + e_{ijk\ell mn} \quad [2]$$

where $Y1_{ijk\ell mn}$ = first-parity DO or DS for cow ℓ that calved in age group m during calendar month n of calving season j in herd i and belonged to survival group k; A1= effect of age group for first calving (15 to 22, 23 to 24, 25 to 26, 27 to 28, 29 to 30, 31 to 32, or 33 to 36 mo); C = effect of calendar month; and H, S, and e are as defined for model [1].

Records for final score (**FS**) and 14 appraisal traits were examined with a model similar to that used for DO and DS:

$$Y1_{ijk\ell mp} = A1_m + D_p + H_{ij} + S_k + e_{ijk\ell mp} \quad [3]$$

where $Y1_{ijk\ell mp}$ = first-parity type score for cow ℓ that was appraised in age group m during lactation stage p in herd i on appraisal date j and belonged to survival group k; A1= fixed effect of age group for first appraisal (15 to 28, 29 to 30, 31 to 32, 33 to 34, 35 to 36, 37 to 38, or 39 to 48 mo); D = effect of lactation stage (1 to 60, 61 to 120, ..., 241 to 300, 301 to 400, >400 DIM, or <60 d before next calving); H = effect of herd-appraisal date; and S and e are as defined for model [1].

Similar analyses for all traits except type traits were conducted for later parities to determine the relative emphasis given to the same traits when culling during second and third lactations. Survival groups were S_2 and S_{3+} (cow had ≥3 records) for parity 2, and S_3 and S_{4+} for parity 3. Calving-age groups for DO and DS were ≤36, 37 to 40, 41 to 44, and ≥45 mo for parity 2 and ≤49, 50 to 54, 55 to 59, and ≥60 mo for parity 3.

Data for parities 1, 2, and 3 were analyzed separately and by individual calving year so that changes in selection emphasis could be observed across time. Analysis was limited to calving years before 2001 for parity 1, 2002 for parity 2, and 2003 for parity 3 to allow cows an opportunity to survive to parity 4. The initial calving year varied by trait, depending on data availability.

Least squares means for survival groups were differences in yields, SCS, DO, DS, or type scores between cows with a successive record and those culled during the immediate lactation. The least squares means also were converted to a standardized basis by dividing by the standard deviation for each year, trait, and parity so that the trait emphasis could be expressed relative to milk yield and compared with current trait emphases in LNM. The measures of selection intensity were derived separately for each trait from all animals with records available for that trait; an animal was not required to have records for all traits to be included in the comparison. Selection intensity for milk yield was assigned a value of 100% for each year.

RESULTS AND DISCUSSION

Table 1 shows the number of cows with first-parity yield records that were included in the study by year of first calving. The requirement for protein data limited the number of cows included from the 1980s; however, the number of cows increased rapidly from 138,850 cows in 1982 to 475,729 in 1990, with only a small increase through the 1990s. Means of first-parity standardized milk yield increased between 1982 and 2000, with a mean annual increase of 176 kg/yr; the largest increase was 537 kg in 1997. The annual increase for mean standardized milk yield of all DHI Holsteins was 190 kg for cows born between 1980 and 1998 (Animal Improvement Programs Laboratory, 2006a). That increase was based on DHI cows with milk and fat data but not necessarily protein data; DHI cows without protein data were primarily from California (Animal Improvement Programs Laboratory, 2006b).

Table 1 also shows the least squares differences in standardized first-parity milk yield by year of first calving for cows in the longer survival groups compared with cows retained in the herd for only 1 lactation. Cows with ≥2 lactations had 1,071 kg more milk during first

Table 1. Number of cows with protein records, mean standardized first-parity milk yield, and least squares difference (advantage) in first-parity milk yield by year of first calving for cows that survived for ≥2, 2, 3, and ≥4 parities compared with cows with only a first-parity record

Year of first calving	Cows (no.)	First-parity milk yield (kg)	First-parity yield advantage (kg) based on parities survived			
			≥2	2	3	≥4
1982	138,850	8,193	1,071	800	1,104	1,230
1984	291,684	8,135	1,091	868	1,122	1,226
1986	398,955	8,502	1,122	920	1,162	1,250
1988	445,828	8,850	1,170	998	1,213	1,277
1990	475,729	9,176	1,178	1,032	1,234	1,265
1992	477,628	9,600	1,239	1,119	1,305	1,298
1994	455,485	9,962	1,283	1,175	1,350	1,331
1996	437,689	10,117	1,239	1,157	1,301	1,273
1997	477,537	10,654	707	645	764	723
1998	498,975	10,912	642	569	710	663
1999	497,875	11,301	694	627	767	704
2000[1]	365,627	11,370	673	609	722	699

[1]Incomplete year.

lactation in 1982 than those with only 1 lactation. That advantage increased to 1,239 kg in 1996. Surprisingly, the least squares difference dropped sharply in 1997 to 707 kg and has leveled off since then.

A change in methodology was the primary cause for the abrupt decline in survival-group differences for first-parity milk yield between 1996 and 1997. In 1999, the best prediction (**BP**) method (VanRaden, 1997) was implemented to predict 305-d yield from test-day data, including extension of short (<305 d) records (VanRaden et al., 1999). Because of incomplete test-day data for earlier years, BP was applied only for cows that calved during January 1997 or later. Norman et al. (1999) showed that the BP method predicted 305-d milk yield for low-producing cows more favorably than did projection factors (Wiggans and Powell, 1980) used in conjunction with the test-interval method (Sargent et al., 1968). Unpublished studies (P. M. VanRaden, Animal Improvement Programs Laboratory, ARS, USDA, Beltsville, MD, personal communication) also showed that projected mean from BP was 600 kg higher for 150-d records than from projection factors. An increase in estimates of 305-d yield for low-producing cows was the primary reason that standardized lactation means of Holstein cows with records eligible for national genetic evaluations increased by 6% between 1996 and 1997 calving years in contrast to mean increases of 1.6% from 1980 to 1996 and 1.2% from 1997 to 2004 (Norman and Thornton, 2006). The BP method was implemented for yield traits and SCS but not for DO or DS.

Cows retained in the herd for 2, 3, and ≥4 parities averaged 800, 1,104, and 1,230 kg more first-parity milk, respectively, during 1982 than did cows culled before parity 2 (Table 1). Those first-parity differences in milk yield are larger than the 540, 873, and 905 kg, respectively, reported by Keown et al. (1976) for 1968. During the 1980s, cows that were most productive during their first lactations were retained in the herd the longest, but the survival advantage associated with higher first-parity milk yield (304 and 430 kg in 1982 for cows retained for 3 and ≥4 lactations, respectively, compared with those retained for 2 lactations) declined with time (corresponding advantages of 202 and 233 kg during 1990). After 1990, cows that survived ≥4 lactations had slightly lower first-parity yield than those retained for 3 lactations. The abrupt decline in milk superiority (43%) from 1996 to 1997 for the cows that were retained for ≥2 lactations was also evident for all other survival groups.

Mean standardized first-parity yields as well as least squares first-parity yield differences between survival groups are shown in Table 2 for fat and in Table 3 for true protein by year of first calving. Mean first-parity yield from 1982 through 2000 increased from 298 to 415 kg for fat (Table 2) and from 246 to 341 kg for true protein (Table 3). Survival-group trends for advantage in first-parity fat and true protein yields were similar to those for milk yield. Abrupt declines in yield superiority (35% for fat and 49% for true protein) again were found between 1996 and 1997 for cows that survived ≥2 lactations compared with cows culled before parity 2.

Number of cows with SCS data (Table 4) increased from 105,989 in 1987 to 507,970 in 1999. In 1988, only 41% as many cows were tested for SCS as for protein, but 3% more were tested for SCS than for protein in 2000. Mean first-parity SCS was 3.38 in 1987 and 3.13 in 2000 and showed considerable fluctuation by year. Cows retained for ≥2 lactations had a distinct advantage for lower first-parity SCS (decreases of 0.34 to 0.62) compared with cows culled before parity 2. The

Table 2. Mean standardized first-parity fat yield and least squares difference (advantage) in first-parity fat yield by year of first calving for cows that survived for ≥2, 2, 3, and ≥4 parities compared with cows with only a first-parity record

Year of first calving	First-parity fat yield (kg)	First-parity yield advantage (kg) based on parities survived			
		≥2	2	3	≥4
1982	298	33	24	33	38
1984	298	33	25	34	37
1986	309	33	27	34	38
1988	322	35	29	36	39
1990	334	34	29	36	37
1992	352	35	31	37	37
1994	362	35	32	37	37
1996	369	34	32	36	36
1997	386	22	20	24	23
1998	395	19	16	20	20
1999	412	21	18	23	21
2000[1]	415	20	18	21	21

[1]Incomplete year.

advantage increased until 1994 but declined sharply in 1997, primarily the result of implementing the BP method. For all calving years, the advantage in first-parity SCS for cows that survived for >1 lactation over those that were culled before parity 2 increased with the number of parities survived.

Table 5 shows mean first-parity DO, which increased from 120 d for 324,545 cows that calved in 1982 to 141 d for 468,755 cows that calved in 1999. That increase agrees well with the decrease in daughter pregnancy rate of 5.43% between DHI Holstein cows born in 1980 and those born in 1997 (Animal Improvement Programs Laboratory, 2006a), which corresponds to a 21.7-d increase in DO (1% decrease = 4-d increase in DO). Cows that survived ≥2 lactations conceived earlier than those retained for only 1 lactation. Although the DO advantage for survivors (≥2 lactations) declined slightly through the 1980s, it increased from 1988 (17 d) to 2000 (43 d). In 1982, cows culled during first lactation had 19, 17, and 23 more first-parity DO than those with 2, 3, and ≥4 lactations, respectively; those differences increased to 34, 41, and 52 more DO by 2000. Producers are milking nonpregnant cows longer. Because of the negative genetic relationship between yield and fertility (Dematawewa and Berger, 1998), increased emphasis on milk yield resulted in increased DO despite direct selection for fewer DO when culling. After 1984, cows that survived for 3 lactations generally had an increasing advantage for DO over those that survived for 2 lactations (7 d fewer open in 2000). Likewise, those that survived for ≥4 lactations had a distinct and increasing DO advantage (6 to 11 d fewer open) compared with those that survived for 3 lactations.

Table 3. Mean standardized first-parity true protein yield and least squares difference (advantage) in first-parity true protein yield by year of first calving for cows that survived for ≥2, 2, 3, and ≥4 parities compared with cows with only a first-parity record

Year of first calving	First-parity true protein yield[1] (kg)	First-parity yield advantage (kg) based on parities survived			
		≥2	2	3	≥4
1982	246	31	23	32	35
1984	245	31	25	32	35
1986	254	32	27	33	36
1988	260	33	28	34	36
1990	271	33	29	35	36
1992	284	36	33	38	38
1994	295	37	34	39	38
1996	299	35	33	37	36
1997	315	18	16	19	18
1998	324	17	15	19	18
1999	338	19	17	21	19
2000[2]	341	18	17	20	19

[1]True protein yield before May 2000 was estimated by subtracting 0.0019 times the milk yield from the CP yield.

[2]Incomplete year.

Table 6 shows the number of cows with recorded DS, around 30% of the number available for other traits in recent years. This trait is measured on a 5-point scale from 1 (no problem during calving or unobserved) to 5 (extreme difficulty during calving) (Van Tassell et al., 2003). Mean first-parity DS ranged from 1.64 in 1985 (not shown) to 1.77 in 2000. Although DS has a negative relationship with survival, cows with ≥2 parities had only slightly easier first parturitions (lower DS by 0.10 to 0.14) than those with only 1 parity. The number of lactations that cows completed generally increased as their first-parity DS decreased; DS advantage for cows that survived for 3 lactations was the same as or greater than that for cows that survived for 2 lactations for 17 of the 21 yr analyzed (not shown). Overall culling rate is not affected much by DS, perhaps because of the low frequency of extremely difficult calvings (Van Tassell et al., 2003).

Table 7 shows the number of DHI cows appraised for FS by year of first calving as well as actual FS mean during first lactation and the amount of selection on the trait during culling. Final score in first parity is measured on a scale from 50 to 89. Mean first-parity FS of DHI Holsteins decreased from 78.2 to 76.1 between 1983 and 2000. However, FS standards changed over time, and Holstein Association USA made an effort to control the mean of cows that were scored each year (J. Connor, Holstein Association USA, Brattleboro, VT, personal communication). Therefore, the decline in mean FS provides no evidence that conformation of the population has deteriorated, and estimates of genetic trend indicate that it improved (Tsuruta et al., 2002). Cows with ≥2 parities had higher FS by 1.4 to 1.9 than those with only 1 parity. The number of lactations that cows completed consistently increased as FS that was

Table 4. Number of cows with SCS records, mean standardized first-parity SCS, and least squares difference (advantage) in first-parity SCS by year of first calving for cows that survived for ≥2, 2, 3, and ≥4 parities compared with cows with only a first-parity record

Year of first calving	Cows (no.)	First-parity SCS	First-parity SCS advantage based on parities survived			
			≥2	2	3	≥4
1987	105,989	3.38	–0.37	–0.26	–0.34	–0.47
1988	184,148	3.20	–0.41	–0.32	–0.39	–0.50
1990	261,549	3.02	–0.51	–0.39	–0.48	–0.63
1992	336,422	3.16	–0.58	–0.45	–0.55	–0.71
1994	453,942	3.13	–0.62	–0.49	–0.59	–0.75
1996	445,807	3.09	–0.58	–0.46	–0.56	–0.72
1997	481,527	3.07	–0.34	–0.23	–0.32	–0.46
1998	502,974	3.06	–0.36	–0.26	–0.35	–0.48
1999	507,970	3.07	–0.35	–0.25	–0.34	–0.46
2000[1]	375,580	3.13	–0.34	–0.24	–0.33	–0.44

[1]Incomplete year.

Table 5. Number of cows with days open (DO) records, mean first-parity DO, and least squares difference (advantage) in first-parity DO by year of first calving for cows that survived for ≥2, 2, 3, and ≥4 parities compared with cows with only a first-parity record

Year of first calving	Cows (no.)	First-parity DO (d)	First-parity DO advantage (d) based on parities survived			
			≥2	2	3	≥4
1982	324,545	120	–20	–19	–17	–23
1984	356,007	121	–18	–18	–16	–22
1986	399,445	122	–18	–14	–15	–22
1988	425,235	125	–17	–14	–15	–21
1990	447,519	127	–20	–16	–18	–25
1992	449,924	127	–22	–16	–20	–29
1994	435,105	131	–24	–18	–22	–31
1996	427,358	136	–29	–21	–28	–37
1997	447,555	137	–37	–29	–35	–46
1998	466,098	143	–41	–32	–41	–52
1999	468,755	141	–42	–34	–42	–52
2000[1]	344,445	142	–43	–34	–41	–52

[1]Incomplete year.

Table 6. Number of cows with dystocia score (DS) records, mean first-parity DS, and least squares difference (advantage) in first-parity DS by year of first calving for cows that survived for ≥2, 2, 3, and ≥4 parities compared with cows with only a first-parity record

Year of first calving	Cows (no.)	First-parity DS	First-parity DS advantage based on parities survived			
			≥2	2	3	≥4
1982	10,179	1.68	–0.13	–0.11	–0.11	–0.15
1984	15,133	1.67	–0.14	–0.09	–0.13	–0.18
1986	24,753	1.66	–0.10	–0.10	–0.09	–0.11
1988	30,548	1.67	–0.12	–0.08	–0.13	–0.15
1990	43,380	1.66	–0.11	–0.10	–0.10	–0.13
1992	61,870	1.78	–0.14	–0.10	–0.13	–0.18
1994	72,955	1.71	–0.13	–0.10	–0.12	–0.17
1996	89,492	1.70	–0.12	–0.09	–0.12	–0.16
1997	98,863	1.72	–0.10	–0.07	–0.10	–0.12
1998	136,598	1.70	–0.10	–0.07	–0.09	–0.14
1999	143,050	1.73	–0.11	–0.07	–0.10	–0.15
2000[1]	108,117	1.77	–0.12	–0.09	–0.11	–0.16

[1]Incomplete year.

Table 7. Number of cows with type records, mean first-parity final score (FS), and least squares difference (advantage) in first-parity FS by year of first calving for cows that survived for ≥2, 2, 3, and ≥4 parities compared with cows with only a first-parity record

Year of first calving	Cows (no.)	First-parity FS	First-parity FS advantage based on parities survived			
			≥2	2	3	≥4
1983	82,435	78.2	1.9	1.1	1.8	2.3
1984	86,040	78.0	1.8	1.1	1.8	2.3
1986	113,118	77.6	1.8	1.2	1.8	2.2
1988	125,071	77.2	1.9	1.2	1.9	2.4
1990	144,387	76.9	1.8	1.3	1.8	2.3
1992	146,760	76.8	1.9	1.3	2.0	2.4
1994	138,262	76.8	1.7	1.2	1.7	2.2
1996	124,103	76.4	1.7	1.2	1.7	2.0
1997	117,241	76.3	1.5	1.1	1.5	1.9
1998	121,441	76.1	1.6	1.2	1.6	1.9
1999	121,454	76.2	1.4	1.0	1.5	1.8
2000[1]	117,655	76.1	1.4	1.1	1.4	1.8

[1]Incomplete year.

assigned during first lactation improved. Cows with ≥4 lactations had higher first-parity FS by 0.3 to 0.5 than cows with 3 lactations and by 0.7 to 1.2 than cows with 2 lactations.

First-parity trait means were calculated for cows that calved during 1996 or 1997 (Table 8) to illustrate the effect that conversion to the BP method had within survival groups. Mean first-parity milk yield increased by 933 kg between 1996 and 1997 for cows that survived only 1 lactation compared with 406 kg for cows that survived ≥2 lactations. Corresponding mean increases were 26 and 15 kg for fat and 29 and 12 kg for true protein. Mean first-parity SCS for cows that were culled before parity 2 improved substantially (decrease of 0.22), whereas that for cows that survived ≥2 lactations changed little (increase of 0.03). The first-parity means for 1996 and 1997 provide evidence that the change to the BP method for yield and SCS caused the abrupt decline in apparent selection intensity. No such dramatic change was observed for DO, DS, and FS, which are not adjusted with the BP method. Although the apparent progress for yield and SCS decreased substantially, the actual progress probably did not change much. Because the BP method was not implemented by USDA until 1999 and generally not implemented at all by the dairy records processing centers, predictions of cow yield and SCS that were provided to DHI producers (and could have modified their culling choices) were not changed between 1996 and 1997. Additional research may be needed to examine the predictive capa-

Table 8. First parity-means for standardized yields (milk, fat, and protein), SCS, actual days open (DO), dystocia score (DS), and final score (FS) for cows that first calved in 1996 and 1997 by number of parities that cow survived

First-parity trait	Year of first calving	Parities survived				
		1	≥2	2	3	≥4
Yield, kg						
Milk	1996	9,198	10,436	10,429	10,544	10,369
	1997	10,131	10,842	10,864	10,947	10,747
Fat	1996	343	377	377	381	375
	1997	369	392	393	395	317
Estimated true protein[1]	1996	273	308	308	311	306
	1997	302	320	321	323	317
SCS	1996	3.58	2.93	3.08	2.96	2.79
	1997	3.36	2.96	3.10	2.98	2.83
DO, d	1996	162	131	140	132	122
	1997	168	129	138	131	120
DS	1996	1.79	1.67	1.72	1.68	1.63
	1997	1.79	1.70	1.74	1.70	1.67
FS	1996	75.0	76.8	76.3	76.8	77.1
	1997	74.9	76.6	76.1	76.5	77.0

[1]CP yield − 0.0019 (milk yield).

Table 9. Emphasis when culling during first lactation on yield traits, SCS, days open (DO), dystocia score (DS), and final score (FS) relative to milk yield by year of first calving

Year of first calving	Relative emphasis (%) on first-parity trait						
	Milk yield	Fat yield	True protein yield[1]	SCS	DO	DS	FS
1982	100	86	98	—	–23	–8	—
1984	100	83	97	—	–21	–9	29
1986	100	83	99	—	–20	–7	28
1988	100	82	99	–19	–18	–8	26
1990	100	78	99	–23	–22	–7	26
1992	100	76	101	–25	–23	–9	24
1994	100	75	100	–26	–24	–9	22
1996	100	74	100	–26	–30	–9	23
1997	100	83	91	–31	–61	–11	33
1998	100	77	95	–37	–73	–13	38
1999	100	79	96	–34	–72	–13	31
2000[2]	100	78	95	–33	–74	–15	33

[1]True protein yield before May 2000 was estimated by subtracting 0.0019 times the milk yield from the CP yield.

[2]Incomplete year.

bilities of BP in all situations. Having the most accurate prediction of cow performance is critical for producers to maintain highly profitable operations.

Although DO or DS records were not standardized, considerable change was observed in DO for first calvings between 1992 and 2000 (not shown). Mean first-parity DO increased by 31 d for cows that survived for only 1 lactation and by 11 d for cows that survived for ≥2 lactations. Perhaps because of the availability of bST, some cows that a producer planned to cull at the end of their first lactations were milked longer because their test-day yield during late lactation was enhanced.

The effect of conversion to BP raised some concern about the precision of trait differences between survival groups and the ability to document exactly how selection intensity had changed within and between traits across time. Because the BP method was implemented for milk, fat, and protein yields and SCS at the same time, the relative emphases that producers assigned to those 4 traits during culling can be compared accurately both within and across years.

Table 9 shows the emphases placed on yield and fitness traits when culling US Holstein cows during first lactation relative to an emphasis of 100% for milk yield. Producers valued true protein yield similarly to milk yield (91 to 102% relative emphasis, including years not shown). Emphasis on fat yield was 74 to 86% of the emphasis on milk yield, with slightly less emphasis during the 1990s than the 1980s. Producer emphasis on SCS was 17% of the emphasis on milk yield in 1987 (not shown), but SCS gained culling importance over time (>30% since 1997).

First-parity DO received 18 to 30% of the emphasis of milk yield between 1982 and 1996 (Table 9), even though fertility as measured by pregnancy rate was deteriorating (Animal Improvement Programs Laboratory, 2006a). Emphasis on fertility when culling cows increased during the 1990s, and DO received 72 to 74% of the emphasis on milk yield from 1998 through 2000. The largest increase was between 1996 (30%) and 1997 (61%), which was affected by implementation of BP methodology (VanRaden et al., 1999). Therefore, the apparent increased emphasis on reproduction after 1996 likely represents a moderate overestimate of actual producer emphasis. Although direct selection for fertility when culling cows could slow the decrease in DO, achieving a positive outcome would be easiest through sire and paternal-grandsire selection pathways; that is, by emphasizing bull PTA for daughter pregnancy rate. A more comprehensive study could try to partition changes in DO due to direct and indirect selection and estimate the direct selection for DO that would be required to counteract indirect effects of direct selection for higher yield, which reduces fertility.

Emphasis on DS during first-parity culling (Table 9) was extremely low but gradually increased (8% in 1982 to 15% in 2000) compared with emphasis on milk yield. The increase from 9% in 1996 to 11% in 1997 is small compared with the increase expected from the apparent reduction in emphasis on milk yield caused by implementation of the BP method.

Emphasis on FS relative to milk yield decreased slightly from 29% in 1982 to 23% in 1996. For 1997 calvings, which were affected by implementation of the BP method for yield traits and SCS, relative emphasis on FS increased to 33% even though least square differences between cows with only 1 lactation and those with ≥2 lactations decreased (Table 8). Relative emphasis on

Table 10. Emphasis when culling during first lactation on 14 linear type appraisal traits relative to final score by year of first calving

	Relative emphasis (%) on linear type trait														
Year of first calving	Final score	Stature	Strength	Body depth	Dairy form	Rump angle	Thurl width	Rear legs (side view)	Foot angle	Fore udder attach-ment	Rear udder height	Rear udder width	Udder cleft	Udder depth	Front teat place-ment
1983	100	31	24	30	50	2	25	−7	24	43	55	60	42	13	38
1984	100	29	23	29	49	−2	22	−3	24	48	63	61	49	15	43
1986	100	30	25	32	46	−2	25	−13	27	45	60	61	44	12	40
1988	100	22	21	27	48	1	26	−10	28	53	62	65	50	21	41
1990	100	23	21	27	52	3	24	−14	30	51	62	63	44	17	36
1992	100	19	19	25	46	3	20	−19	35	54	62	65	46	20	37
1994	100	15	20	21	43	5	20	−19	31	55	59	62	43	23	31
1996	100	16	18	24	38	10	17	−18	33	59	61	63	45	27	35
1997	100	13	20	19	40	10	20	−23	36	59	58	63	45	32	31
1998	100	10	15	14	32	9	11	−18	28	62	58	60	45	36	35
1999	100	1	11	5	28	11	5	−23	29	63	60	64	40	33	37
2000[1]	100	6	11	5	23	10	8	−26	28	58	53	56	48	41	34

[1]Incomplete year.

FS reached a high of 38% in 1998, decreased to 31% in 1999, and was 33% (the same as for SCS) in 2000.

Table 10 shows the emphases dairy producers gave to various type appraisal traits compared with that given to FS when deciding which cows to cull during first lactation. Several body traits (stature, strength, body depth, and thurl width) received more relative emphasis from 1983 to 1986 (22 to 32%) than they did from 1997 to 2000 (1 to 20%). In contrast, several udder traits (rear udder height, rear udder width, and udder cleft) received about the same relative emphasis in recent years (40 to 64%) as in earlier years (42 to 63%). Udder depth showed the greatest increase in relative emphasis (13% in 1983 to 41% in 2000). Rear legs (side view) and rump angle received somewhat more attention in recent years, while emphasis on foot angle increased from 24% in 1983 to 36% in 1997 and then declined to 28% by 2000. Dairy form declined from 50% of the emphasis given to FS in 1983 to 23% in 2000.

The changes in relative emphases on type traits reflect the interest of dairy producers in improving health and fitness of their cows. Farmers want high, wide rear udders to hold more milk along with a strong udder attachment, proper teat placement, and good ground clearance to prevent mastitis and to avoid injury. More emphasis is being placed on straighter legs. Increased emphasis on rump angle (Wall et al., 2005) and reversed emphasis on dairy form (Tsuruta et al., 2005) may indicate a growing interest in improving calving ease and fertility.

Table 11 shows differences for second-parity performance between cows with >2 lactations and those culled during second lactation. Most second-parity differences were within 15% of first-parity differences (Tables 1 through 6) except for DO and DS. For parity 2, survivor advantage for DO did not increase over time (22 d fewer in 1982 to 36 d fewer in 2000) as much as it did for parity 1 (20 d fewer in 1982 to 43 d fewer in 2000). Second-parity DS differences for cows retained for additional parities over cows that were culled during the current lactation [−0.04 to −0.10 (not shown)] were about half the differences for parity 1 (−0.10 to −0.14). A decrease in DS advantage for parity 2 was expected as calving difficulty is much less of a problem for later parities than for parity 1 (Dematawewa and Berger, 1997). Until the implementation of BP for calvings in 1997 and later, second-parity differences in milk yield between cows that survived for additional lactations and those retained only for 2 lactations were larger than those reported by Keown et al. (1976).

Table 12 shows the relative emphases placed on second-parity traits when culling during second lactation. True protein again received nearly the same emphasis (92 to 100%) as milk. Fat was valued slightly more relative to milk (80 to 90%) during second lactation than during first (74 to 86%, Table 9), but the greatest extra value was placed on SCS and DO. The increased emphasis on SCS may have resulted from a higher SCS mean for later lactations, which has an increasingly negative impact on the milk price that is received by dairy producers because of quality incentives for low SCC. The increased emphasis on DO may have resulted from lower persistency for later-parity cows than for first-parity cows. From 1996 through 1998, emphasis on SCS increased from 66 to 80% of the emphasis placed on second-parity milk yield, and DO received more emphasis (112 to 131%) than milk yield from 1997 through 2001. However, emphases on SCS and DO relative to milk yield during second lactation decreased slightly during 2001 based on data from the partial year. Because variation in DS was lower for parity 2 than for parity 1, relative emphasis on DS compared with milk

Table 11. Number of cows with second-parity protein records and least squares difference (advantage) in second-parity traits by year of second calving for cows that survived for >2 parities compared with cows with only first- and second-parity records

Year of second calving	Cows (no.)	Second-parity trait: Milk yield (kg)	Fat yield (kg)	True protein yield[1] (kg)	SCS	DO (d)	DS
1982	104,970	1,033	34	29	—	–22	–0.05
1984	217,523	988	33	28	—	–22	–0.04
1986	294,009	1,035	34	29	—	–21	–0.07
1988	318,988	1,044	35	29	–0.52	–20	–0.06
1990	346,375	1,067	34	30	–0.50	–22	–0.06
1992	353,835	1,067	34	30	–0.53	–22	–0.06
1994	346,362	1,117	34	32	–0.54	–24	–0.07
1996	333,796	1,150	35	33	–0.55	–26	–0.05
1997	332,694	801	26	21	–0.36	–32	–0.06
1998	349,978	740	24	20	–0.38	–35	–0.05
1999	379,340	778	25	21	–0.38	–35	–0.05
2000	380,647	765	23	20	–0.38	–36	–0.06
2001[2]	315,660	794	25	21	–0.38	–33	–0.06

[1]True protein yield before May 2000 was estimated by subtracting 0.0019 times the milk yield from the CP yield.

[2]Incomplete year.

yield was greater for parity 2 (Table 12) than for parity 1 (Table 9), even though least squares differences between cows that were culled and those that were retained were smaller for parity 2 (Table 11) than for parity 1 (Table 6).

Table 13 shows differences for third-parity performance between cows with >3 lactations and those culled during third lactation. Advantage of survivors for third-parity yield traits and SCS generally was similar to that for first- and second-parity traits except for a slight decline in survivor advantage for milk and true protein yields during the 1980s. Survivor advantage for third-parity DO increased even less (23 d fewer in 1982 to 30 d in 2000) over time than was found for parity 2. The DS differences for third-parity survivors (–0.03 to –0.06) were less than both first- and second-parity differences. Third-parity differences in milk yield between cows that survived for additional lactations and those retained only for 3 lactations were larger than or about the same as those reported by Keown et al. (1976) even after the implementation of BP for calvings in 1997 and later.

Table 12. Emphasis when culling during second lactation on yield traits, SCS, days open (DO), and dystocia score (DS) relative to milk yield by year of second calving

Year of second calving	Relative emphasis (%) on second-parity trait: Milk yield	Fat yield	True protein yield[1]	SCS	DO	DS
1982	100	90	98	—	–61	–12
1984	100	89	98	—	–62	–10
1986	100	88	99	—	–58	–16
1988	100	89	99	–59	–55	–15
1990	100	84	98	–59	–61	–16
1992	100	82	100	–66	–63	–13
1994	100	81	99	–64	–65	–15
1996	100	80	100	–66	–70	–12
1997	100	86	92	–70	–112	–17
1998	100	85	94	–80	–125	–18
1999	100	84	94	–79	–124	–17
2000	100	81	92	–78	–131	–19
2001[2]	100	83	93	–75	–115	–19

[1]True protein yield before May 2000 was estimated by subtracting 0.0019 times the milk yield from the CP yield.

[2]Incomplete year.

Table 13. Number of cows with third-parity protein records and least squares difference (advantage) in third-parity traits by year of third calving for cows that survived for >3 parities compared with cows with only first-, second-, and third-parity records

Year of third calving	Cows (no.)	Third-parity trait: Milk yield (kg)	Fat yield (kg)	True protein yield[1] (kg)	SCS	DO (d)	DS
1982	59,898	913	30	26	—	–23	–0.06
1984	143,928	869	29	25	—	–23	–0.04
1986	190,678	919	30	26	—	–22	–0.06
1988	217,757	971	32	27	—	–21	–0.05
1990	227,108	1,006	32	28	–0.47	–21	–0.03
1992	236,661	1,045	32	30	–0.50	–21	–0.04
1994	236,735	1,120	35	32	–0.53	–21	–0.04
1996	228,530	1,211	38	35	–0.54	–22	–0.03
1997	229,687	792	27	20	–0.36	–26	–0.04
1998	221,576	731	24	19	–0.38	–29	–0.04
1999	230,485	751	24	20	–0.39	–30	–0.04
2000	247,341	745	23	19	–0.38	–30	–0.05
2001	250,144	767	24	20	–0.38	–28	–0.05
2002	219,246	815	26	21	–0.33	–21	—[3]
2003[2]	26,348	715	20	19	–0.34	–28	—[3]

[1]True protein yield before May 2000 was estimated by subtracting 0.0019 times the milk yield from the CP yield.

[2]Incomplete year.

[3]Insufficient data.

Comparison of relative emphases on traits when culling during third lactation (Table 14) revealed little change in selection emphasis from that for parity 2 (Table 12). Emphasis on third-parity DO was slightly greater than that for parity 2 during the 1980s and then slightly less during the 1990s.

Emphasis on yield traits in the LNM index (VanRaden and Multi-State Project S-1008, 2006) has decreased for milk yield (5% in 2000 to 0% in 2006), increased slightly for fat yield (21% in 2000 to 23% in 2006), and decreased for true protein yield (36% in 2000 to 23% in 2006). Relative emphases on SCS and type

Table 14. Emphasis when culling during third lactation on yield traits, SCS, days open (DO), and dystocia score (DS) relative to milk yield by year of third calving

Year of third calving	Relative emphasis (%) on third-parity trait: Milk yield	Fat yield	True protein yield[1]	SCS	DO	DS
1982	100	89	99	—	–70	–15
1984	100	91	98	—	–72	–12
1986	100	90	100	—	–66	–16
1988	100	89	99	—	–61	–14
1990	100	86	97	–62	–62	–8
1992	100	82	99	–65	–59	–11
1994	100	83	99	–66	–57	–10
1996	100	85	99	–63	–58	–12
1997	100	80	90	–73	–93	–12
1998	100	85	92	–83	–107	–14
1999	100	86	91	–84	–110	–13
2000	100	83	91	–83	–110	–16
2001	100	84	91	–79	–100	–17
2002	100	84	91	–67	–70	—[3]
2003[2]	100	72	93	–74	–93	—[3]

[1]True protein yield before May 2000 was estimated by subtracting 0.0019 times the milk yield from the CP yield.

[2]Incomplete year.

[3]Insufficient data.

composites (udder, feet/legs, and body size) generally have remained the same. Much of the decrease in emphasis on yield traits resulted from the addition of new fitness traits (calving ease, daughter pregnancy rate, and stillbirth) and shifts in emphasis on productive life. Although the changes in emphasis for yield traits differed between LNM and culling, both showed an increase in the importance of fitness traits.

CONCLUSIONS

Producers placed different emphases on yield and fitness traits when culling US Holstein cows, but the relative emphasis among traits has remained comparatively consistent since 1982 regardless of parity. True protein yield received nearly the same emphasis (90 to 101%) as milk yield, whereas emphasis on fat yield relative to milk yield was lower (72 to 91%). Part of the greater emphasis for protein may be explained by the higher correlation of milk yield with protein yield than with fat yield (Schutz et al., 1990). The value of a lower SCS has increased in importance, and emphasis on SCS relative to milk yield increased from 17% in 1987 to 33% in 2000 for parity 1; even greater emphasis was placed on SCS for later parities (59 to 84%). Although DO has increased in the US Holstein population over time because of its correlation with milk yield, it has received considerable culling emphasis since 1997 (61 to 131%), particularly for later parities. Selection emphasis on DS relative to milk yield was low (7 to 19%). Emphasis on FS during culling relative to emphasis on milk yield has been low (22 to 38%) in DHI herds over time.

The relative emphases that producers place on yield and fitness traits when culling can be considered when determining which traits to emphasize when selecting bulls for progeny test and active AI service. Those emphases also could be used in the development of software for index-based culling in dairy management systems.

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