Genetic Gains in Lifetime Merit Indexes during the use of three Genetic Evaluation Methods

H.D. Norman[1], F.L. Guinan[1,2] and J.W. Dürr[1]

[1] Council on Dairy Cattle Breeding, Bowie, MD, 20716 USA

[2] University of Wisconsin-Madison, 1675 Observatory Drive, Madison, WI 53706 USA

Abstract

Genetic evaluation procedures available and adopted by U.S. dairy producers have had a positive impact on genetic improvement for a multitude of traits. The objective of this research was to compare the progress in several traits during the use of six evaluation methods. Five additional genetic evaluation procedures were produced by USDA following the daughter-dam comparison initiated in 1915. These included two herdmate comparisons (versions implemented in 1962 and 1968), Modified Contemporary Comparison (MCC, Nov. 1974), Animal Model Evaluation (AME, July 1989), and Genomic Evaluation (GE, Apr. 2009). The MCC was largely based on combining (weighting) information by the inverse of the expected variance of each effect in the model. The AME was assumed to have best linear unbiased prediction properties while including primarily the same effects as the MCC. About two years generally elapses before the results are evident in the milking population as nine months are necessary before their first offspring are born, then more time is required before most of inseminations are based on the new evaluations. Average Estimated Breeding Values (EBV) were derived within each of the evaluation periods. The contribution of several additional traits contributing to the overall gains was derived. The transition to each subsequent evaluation brought increases in the genetic gains with one exception. The reason for the declines in annual genetic gains using AME following MCC remains unresolved. The GE is currently generating higher gains in lifetime merit indexes than the earlier methods, and in the four Holstein composites, gains exceeded twice that from the AME method. Genetic economic gains averaging $51 to $67 per year were evident across the 42-years examined.

Key words: estimated breeding value, genetic evaluations, genetic trend, lifetime merit index, milk yield

Introduction

Genetic evaluations in the United States are calculated for up to 50 traits, depending on the dairy breed. These evaluations support the continuous improvement for most traits, particularly for Holsteins where the number of service bulls provides vast selection opportunities. The evaluations have produced positive genetic changes in many of the traits for the remaining breeds as well, but these changes have been highly dependent on the uniqueness of the limited number of bulls available for use. Milk and fat records became available on an increasing percentage of the U.S. dairy population after the early 1900s. Test for protein yield became feasible in the U.S. on a widespread basis by 1978. Composite indexes were developed for annual income from milk and fat yields (Norman, Dickinson, 1971), then protein yield (Norman, Cassell, 1979) and cheese yield; these incorporated the traits beneficial for different market situations. These were replaced by ones for lifetime net income, (VanRaden, 2000) which accounted for the cost of producing each component. Current composites provided are Net Merit Dollars (tailored to the average U.S. pricing situation), Cheese Merit Dollars (for producers paid for the cheese value of the milk), Fluid Merit Dollars (for the few herds receiving negligible payment for protein), and Grazing Merit Dollars (for herds practicing seasonal calving and/or using a pasture system).

Six different sire evaluation procedures for milk traits have been promoted by USDA since the daughter-dam comparison (DDC) was initiated in 1915. Table 1 shows the six evaluation methods used. The main weakness of the DDC was that the herd environments were usually different for the daughters and their dams. They were not usually milking at the same time. These differences in yields due to herd environments were credited erroneously to the genetic contribution of the daughters' sires. The herdmate comparisons (HC, Miller, Corley 1965) neutralized much of this issue as it compared the yield of each individual daughter of the bull to the yield of all other cows in the herd milking at the same time. The revised improved herdmate comparison (ICC, Plowman, McDaniel, 1968) regressed the daughter-herdmate differences so bulls' initial superiority or inferiority held up (on the average).

As genetic differences surfaced because some producers utilized improved genetics more than others, there were calls to account for genetic differences in the merit of herdmates. The Modified Contemporary Comparison (MCC, Norman 1976) introduced in 1974 adjusted for the genetic merit of the contemporaries' sires. A contemporary is usually defined as a herdmate that is the same age as the daughters. The procedure combined information by weighting all records by the inverse of their expected variance. MCC also incorporated ancestors' predictions into sire evaluations for the first time, which, at the time, often doubled the accuracy of the evaluations. The Animal Model Evaluation (AME, Wiggans, VanRaden, 1991) included the same fixed and random effects as did the MCC. However, the AME was assumed to have "best linear unbiased prediction" properties. In addition to the same AME features, the Genomic Evaluation (GE, VanRaden, 2008) added the benefit of how the DNA data had impacted the genomic predictions historically. The GE is currently used, which is now currently calculated by the Council on Dairy Cattle Breeding which took over this responsibility in 2013 from USDA.

Table 1. Dairy genetic evaluation methods available from the U.S. Department of Agriculture.

U.S. National Evaluation Method	Month and year initiated	Years of impact
Daughter-Dam Comparison (DDC)	1915	"1958" to 1962
Herdmate Comparison (HC)	January 1961	1962 to 1970
Improved Herdmate Comparison (IHC)	July 1968	1970 to 1976
Modified Contemporary Comparison (MCC)	November 1974	1976 to 1991
Animal Model Evaluation (AME)	July 1989	1991 to 2010
Genomic Evaluation (GE)	April 2008 (unofficial) April 2009 (official)	2010 to 2019

Material & Methods

The purpose of this examination was to compare the genetic gains made for the four lifetime merit indexes during the evaluation periods. The same was compared for milk, fat, and protein yields, the first traits having genetic evaluations as well as the largest contributors to composite indexes in the early years.

After obtaining results that were unexpected, a subsequent attempt was initiated to investigate the possible cause of the reduction in genetic gain for milk traits during the AME period. One possible reason could be that selection had been redirected to other traits that had evaluations initiated throughout the AME period. The traits added during the AME period were somatic cell score (SCS) and productive life (PL) in 1994 and daughter pregnancy rate (DPR) in 2003.

Results & Discussion

Table 2. Annual genetic gain in milk traits (U.S. Holsteins and Jerseys) from different evaluation methods.

U.S. National Evaluation Method	Years of Impact	Gain in Milk Yield (kg)		Gain in Fat Yield (kg)		Gain in Protein Yield (kg)	
Cow breed →		HO	JE	HO	JE	HO	JE
Daughter-Dam Comparison (1915)	"1958" to 1962	13	14	0.7	0.7	–	–
Herdmate Comparison (1961)	1962 to 1970	37	44	1.4	1.5	–	–
Improved Herdmate Comparison (1968)	1970 to 1976	66	81	2.0	2.7	0.8	–
Modified Contemporary Comparison (1974)	1976 to 1991	88	99	3.2	3.6	2.4	3.0
Animal Model Evaluation (1989)	1991 to 2010	75	87	2.5	3.0	2.4	2.7
Genomic Evaluation (2009)	2010 to 2019	107	94	5.6	4.3	4.1	3.6

The results of annual genetic gains achieved within these evaluation periods are shown in Table 2. The annual gain in milk yield for Holsteins and Jerseys from DDC during the only four years where records were in the computerized database were 13 and 14 kgs. During the initial eight years using the 'original' USDA herdmate comparison, the annual gains were 37 and 44 kgs for the two breeds, respectively. During the eight years when the 'improved' herdmate comparison was used, the annual gains were 66 and 81 kgs. During the 15 years when MCC was available to producers, the annual gains for milk yields were 88 and 99 kgs. Each introduction of new methodology from 1960 to 1974 was associated with an 18 to 37 kg increase in the rate of genetic gain for milk yield.

It is noteworthy that the implementation of the Animal Model evaluation was the only revised procedure that resulted in a decline in the rate of gain for milk yield for the two breeds (75 and 87 kgs), respectively. The Genomic Evaluation produced increases in genetic gain (32 and 7 kg) above that achieved during the AME period.

The results of genetic gain in fat yield presents a similar picture. The gains for Jerseys exceeded those for Holsteins prior to the GE period. During AME, gains were 2.5 and 3.0 kg, respectively, where gains were 3.2 and 3.6 kg from MCC. Annual gains from GE were reversed with 5.6 and 4.3 kgs, respectively. Again, there were increases in genetic gains with each new method except for annual declines of 0.7 and 0.6 kgs in the transition from MCC to AME. Protein produced similar results to milk and fat yields, albeit available for fewer years.

The gains in the four lifetime merit indexes made during the last three evaluation periods are in Table 3. These represent the gains achieved in the current composite merits, almost exclusively before the emphases in these indexes were assigned, because merit indexes are recalculated frequently based on incomes and costs. The composites are highly influenced by the gains achieved in the milk traits using the different evaluation methods although they also represent the progress in dozens of other traits, sometimes prior to their availability. Some of the gains in merit indexes are attributed to changes in conformation, although the conformation appraisal evaluations have not been changed

Table 3. Annual genetic gains in lifetime merit indexes (Holsteins and Jerseys) from different evaluation methods.

U.S. National Evaluation Method	Gain in Net Merit ($)		Gain in Cheese Merit ($)		Gain in Fluid Merit ($)		Gain in Grazing Merit ($)	
Cow breed →	HO	JE	HO	JE	HO	JE	HO	JE
Modified Contemporary Comparison	46	61	46	61	48	61	34	44
Animal Model Evaluation	45	49	46	49	43	49	34	36
Genomic Evaluation	138	85	124	86	112	78	115	69

Table 4. Annual genetic change in three fitness traits for Holsteins and Jerseys during six evaluation periods.

U.S. National Evaluation Method	Years of impact	Genetic change in Productive Life (mo.)		Genetic change in Somatic Cell Score (units)		Genetic change in Daughter Pregnancy Rate (%)	
Cow breed →		HO	JE	HO	JE	HO	JE
DDC	1958 to 1962	N.A.	N.A.	N.A.	N.A.	-0.230	-0.185
HC	1962 to 1970	0.19	0.45	N.A.	N.A.	-0.221	-0.182
IHC	1970 to 1976	0.35	0.77	N.A.	N.A.	-0.290	-0.218
MCC	1976 to 1991	0.33	0.57	+0.013	+0.012	-0.445	-0.437
AME	1991 to 2010	0.20	0.24	0.000	+0.012	-0.335	-0.388
GE	2010 to 2019	0.76	0.63	-0.030	0.000	+0.031	-0.309

significantly since near 1980. Some of the differences in merit indexes are coming from changes in other correlated traits, currently evaluated but not provided earlier. The MCC delivered yearly gains of 46 and 61 Net Merit Dollars for Holsteins and Jerseys. The AME produced less, 45 and 49 dollars. MCC and AME produced similar annual gains in Cheese Merit and Grazing Merit for Holsteins, although MCC exceeded AME for all lifetime indexes for Jerseys. The GE answered with impressive gains of 138 and 85 dollars; especially noteworthy was the progress for Holsteins. In addition to the large increases in genetic gains from the GE implementation, the increases in accuracy of the evaluations were as impressive (not shown).

An attempt was made to try to determine the possible cause for the reduction in genetic gain for milk traits using AME, an examination was made of the changes in other traits that had evaluations initiated throughout the AME period. One possibility was that selection had been redirected to those. Genetic changes for these traits within each evaluation periods were derived and are in Table 4. If selection was redirected toward these three newly evaluated traits, genetic gain should have been produced for these, and would have suggested that was the (possible) reason for the reduced gains for the three milk traits.

Table 5 shows the genetic change in PL did not increase during the animal model evaluation period; in fact, it was lower than during the MCC evaluation period for both Holsteins (0.20 vs 0.33) and Jerseys (0.24 vs 0.57). In addition, the genetic changes in SCS were extremely small showing little evidence of genetic improvement during any of the three relevant periods. The genetic declines in DPR were unfortunate, i.e., negative for 11 of the 12 breed-evaluation periods. However, these declines in fertility should have been expected due to the antagonism between reproduction and the milk yield traits (the cows energy state) as a fertility evaluation was available only for the last few years the animal model was used. The expected years of impact for DPR during

Table 5. Annual and total genetic change in selected (economic) traits between 1977 and 2019.

Trait	Units	Annual Change (HO)	Annual Change (JE)	Total Change (HO)	Total Change (JE)
Milk yield	kg	86	94	3,620	3,927
Fat yield	kg	3.42	3.49	144	147
Protein yield	kg	2.76	3.02	116	127
Productive Life	months	0.36	0.43	15.12	18.06
Somatic cell score[1]	units	-0.006	0.009	-0.204	0.306
Daughter Pregnancy Rate	%	-0.30	-0.39	-12.60	-16.38
Net Merit	$	63	62	2,630	2,596
Cheese Yield Merit	$	63	62	2,642	2,598
Fluid Merit	$	60	60	2,510	2,528
Grazing Merit	$	52	47	2,168	1,954

[1] SCS is the annual average change since 1985 as EBV were not available prior to that year.

the AME period would be even less, about five years. The decline in DPR was greater during the animal model evaluation period than for 3 of the 4 earlier methods for both Holsteins and Jerseys, the exception being during the MCC period. The genetic gains achieved since 1977 reflect the effectiveness of the genetic evaluations available to producers and their willingness to utilize them. The six individual traits shown below represented 100%, 78%, and 68% of the combined weight used in Net Merit $ when the evaluation methodology changed (1991, 2010, and 2019, respectively).

The genetic gains realized can be affected by many factors. The number of bulls that AI organizations enrolled in progeny testing is one clear example of a reason why genetic gains increased over time. The number of bulls entering progeny test increased prior to the genomic era so each new revision should have shown greater gains, simple due to this.

Noteworthy also is the Jerseys outgained the Holsteins, even with its much smaller breed population. In 1968 the American Jersey Cattle Association stressed the need to achieve higher levels of milk yield to remain competitive. They initiated an educational effort through their breed magazine, and it seems their breeders accepted the improved herdmate comparisons more quickly than did those of the other breeds.

A possible reason why the AME did not deliver the gains achieved by the MCC might be that some dams of bulls selected for AI service during the Animal Model Evaluation period were ones that received considerable preferential treatment and their genetic evaluations were over evaluated.

Conclusions

Substantial genetic gain has been made in the last 42 years for many of the traits having high economic importance to the dairy industry, especially milk, fat, and protein yields. These were the traits that had evaluations available the longest time and were the most visible financially to the producers. The genetic gains made for these three traits were largely responsible for keeping dairy products affordable for consumers. Unfortunately, the fertility traits showed a decline throughout most of the periods. This could have been prevented had it been addressed, as calving intervals were available on many of the individual animals throughout the entire period when records were computerized.

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