Comparison of Genetic Evaluations from Animal Model and Modified Contemporary Comparison

H. D. NORMAN, R. L. POWELL, and G. R. WIGGANS
Animal Improvement Programs Laboratory
Agricultural Research Service, USDA
Beltsville, MD 20705-2350

ABSTRACT

Comparisons were made between characteristics of Modified Contemporary Comparison and animal model evaluations with data available for January 1989 USDA-DHIA genetic evaluations. The animal model system's requirement that cows have a valid first lactation record resulted in a decrease in cows and daughters included. New flexible comparison groups were slightly larger for small herds and much smaller for large herds, which resulted in overall smaller and more uniform-sized comparison groups. Determining the optimal method of defining management groups was not undertaken. Correlations between bull evaluations from the two procedures ranged from .92 to .95 across breeds. Increases in reliability over repeatability were substantial for bulls with limited daughter information and small for widely used bulls. Correlations between evaluations for cows born in 1985 were .92 to .96, whereas those for cows born in 1980 (old enough to have daughters affecting animal model evaluations) were lower (.90 to .93), as expected. Reliabilities for cows were .02 to .05 higher than repeatabilities. Cows with more daughters increased more in evaluation and accuracy between the two procedures and were genetically superior. Bulls and cows with more prior information, cows with higher past evaluations, and Holstein bulls with higher past evaluations tended to have larger increases in PTA. Genetic trend estimates were different for the animal model, which resulted in changes in evaluations of various magnitudes depending on breed, sex, and birth year of animal.
(Key words: animal model, Modified Contemporary Comparison, genetic evaluation)

Abbreviation key: CI = Cow Index, CI$ = Cow Index dollars, DE = daughter equivalent, MCC = Modified Contemporary Comparison, REL = reliability, RPT = repeatability.

INTRODUCTION

Implementation of an animal model for USDA-DHIA genetic evaluations in July 1989 (9, 10) was the first major change in national evaluation methodology since the Modified Contemporary Comparison (MCC) was implemented in 1974 (2). Prior to animal model implementation, January 1989 evaluations were computed with both animal model and MCC procedures using the same data to investigate effects of methodology on evaluations. The purpose of this study was to compare the following aspects of animal model and MCC results: evaluations, comparison group composition (management groups versus modified contemporary groups), and accuracy measures (reliability versus repeatability). In addition, relationships between measures of genetic merit (correlation, trend, and potential bias) were investigated.

MATERIALS AND METHODS

Data

Data available for January 1989 MCC evaluations resulted in animal model evaluations for 13 million cows and 400,000 bulls. To limit computing effort, three subsets of matched cow evaluations were examined: cows born in 1985, cows born in 1980, and cows in

Received November 26, 1990.
Accepted February 5, 1991.

the top 10% for Cow Index dollars (CI$). Cows born in 1985 were chosen because they constitute the genetic base group. However, these cows were too young for us to examine the effect on evaluations from including progeny information. Therefore, cows born in 1980 were chosen as the second data subset because they had the time opportunity for five lactations (the maximum used in the animal model) or daughters to be included in animal model evaluations. The third data subset comprised those cows that met requirements for MCC elite status, except that the minimum for CI$ was lowered to include 10% of eligible cows (5). These cows are of interest as potential bull-dams. Additional requirements for elite status (5) are 1) cow is registered, including identity enrollment for some breeds; 2) cow's number in management groups averaged at least 4 across lactations; 3) cow last calved within 25 mo of deadline for data receipt; and 4) cow's last record indicator showed her to be alive. For Holsteins, the third data subset included only cows born in 1980 and 1985.

Bull evaluations were compared only for those sires with at least 10 daughters in both animal model and MCC evaluations. The USDA-DHIA animal model system evaluates all bulls during each semiannual evaluation, whereas the MCC evaluated only bulls with new information added for any particular semiannual evaluation (1). To compare evaluations based on similar information, only bulls with a January 1989 MCC evaluation were included. Bulls without a January 1989 MCC evaluation could have had evaluations on file meeting minimum number of daughter requirements but were not included because they had insufficient new information to be resummarized under MCC. Had they been included, there would have been wide discrepancy in the number of daughters included in the two evaluations.

Edits for the two systems differed slightly. For example, a first lactation record is required in the animal model system but not in the MCC. Also, a maximum of 5 records is included in animal model evaluations, whereas all records per daughter were included in MCC evaluations. Additional differences between the two evaluation procedures are described by Wiggans and VanRaden (10).

Analysis

Differences in number of daughters per bull were examined for the two procedures. Mean numbers of lactation records and SD were calculated for cows born in 1980 to describe the size of comparison groups for the animal model (management groups) and the MCC (modified contemporaries). Mean number of lactation records in management groups also were computed and stratified according to number of MCC modified contemporaries to show the relationship between the two grouping methods.

Evaluations by MCC were adjusted by the amount of the base change to remove this effect from comparisons and to make statistics such as mean differences and absolute differences more meaningful. The amount of the base change was the MCC genetic merit of cows born in 1985 (10). Mean PTA milk and reliabilities (REL) from the animal model and mean PD or Cow Index (CI) milk and repeatabilities (RPT) from the MCC were calculated as well as correlations between animal model and MCC evaluations. Differences between animal model and MCC evaluations and correlations of those differences with MCC evaluations and RPT were computed to identify animals most affected by the animal model system. Means, differences, and correlations were examined by breed, sex, birth year, RPT level, number of daughter equivalents (DE), and genetic merit.

RESULTS

Numbers of daughters for animal model bull evaluations and decreases from MCC numbers are in Table 1. Most MCC evaluations had information from more daughters

TABLE 1. Numbers of daughters for animal model bull evaluations and decreases from Modified Contemporary Comparison numbers by breed.

Breed	Number	Decrease
		(%)
Holstein	1,167,692	5.6
Jersey	95,600	7.8
Guernsey	37,882	8.6
Brown Swiss	18,372	10.4
Ayrshire	11,757	13.4

TABLE 2. Mean numbers of lactation records in comparison group and SD for cows born in 1980 by breed.

Breed	Modified contemporary		Management group	
	$\overline{X}$	SD	$\overline{X}$	SD
Holstein	28	46	12	14
Jersey	29	29	15	12
Guernsey	14	9	9	4
Brown Swiss	13	10	8	4
Ayrshire	17	13	9	5

than for animal model evaluations because of the requirement for a first lactation record in the animal model system. Decrease in number of daughters was smallest for Holsteins (5.6%) and largest for Ayrshires (13.4%). The smaller decrease in number of daughters for Holsteins than for the other breeds may result from the lower percentage of Holstein daughters sired by bulls with small numbers of daughters. In other breeds, proportionately more daughters were sired by bulls with only slightly more than the 10 daughters required for release of the evaluation. Requiring a usable first lactation record may have not only eliminated some cows from evaluation but also decreased the number of daughters for their sire below the 10 required, eliminating the bull from this study. Another factor contributing to the smaller decrease for Holsteins was the incorporation of records for Red and White dairy cattle into a combined animal model evaluation for Holsteins and Red and Whites (10), which increased the number of daughters for some sires.

By design, size of comparison groups was smaller for the animal model than for MCC (9, 10). Mean numbers of lactation records in comparison groups and SD are in Table 2 for cows born in 1980. As with MCC modified contemporary groups, management group size was larger for Holsteins and Jerseys than for the other breeds. The larger reduction in SD of comparison group size for Holsteins reflects their separate groupings for registered and grade animals. Mean size of comparison group was reduced by 36 to 57% with the animal model and was much more uniform across cows, as indicated by the reduction in SD of 56 to 70%.

Effect of the animal model's flexible management group definition on different sizes of modified contemporary groups was examined. The number of lactation records in a cow's management group includes hers and can include those of her paternal half-sibs (10); therefore, the number of lactation records in her management group would be at least one higher than the number of MCC modified contemporaries (3) if the same herdmates were considered. Table 3 shows mean numbers of lactation records in a management group according to number of modified contemporaries for cows born in 1980. Mean number of modified contemporaries in each category was near the midpoint of the range. For example, the mean number of modified contemporaries in the 3 to 5 category was near 4, which, if adjusted to include the cow herself as in the animal model, would be 5. As shown in Table 3, mean management group sizes were slightly larger for the animal model than for the MCC for the smallest modified contemporary group but considerably smaller for larger groups. Even though fewer cows were compared directly with the flexible grouping of the animal model, they tended to be more nearly contem-

TABLE 3. Mean numbers of lactation records in management group for cows born in 1980 according to number of modified contemporaries and breed.

Breed	Number of cows in modified contemporary group				
	3 to 5	6 to 10	11 to 20	>20	All
Holstein	5.7	7.3	9.0	19.7	12.1
Jersey	5.7	7.6	9.8	22.3	14.7
Guernsey	5.6	6.9	8.7	13.0	8.6
Brown Swiss	5.3	6.8	8.8	13.0	8.0
Ayrshire	5.2	6.7	8.3	13.5	8.9

TABLE 4. Means and SD for bull PD milk adjusted for genetic base change and PTA milk, correlations between adjusted PD and PTA, and mean repeatabilities (RPT) and reliabilities (REL) by breed.

Breed	Number of bulls	Adjusted PD milk		PTA milk		Mean RPT	Mean REL	Correlation
		$\overline{X}$	SD	$\overline{X}$	SD			
		(kg)						
Holstein	11,153	–54	282	25	312	.43	.58	.94
Jersey	922	–35	238	–47	254	.43	.60	.95
Guernsey	373	8	210	–4	224	.46	.63	.93
Brown Swiss	238	–23	254	–52	265	.46	.63	.93
Ayrshire	211	18	190	15	198	.48	.61	.92

porary. Determining the optimal method of defining management groups was not undertaken in this study and so remains unresolved (4).

Characteristics of bull evaluations for milk yield and their accuracy are given in Table 4 by breed for the two evaluation procedures. Relationship of mean PTA with mean PD adjusted for the genetic base change varied by breed. The largest discrepancy was for Holsteins. The effect of the base change was most different between the sexes for Holsteins and suggested that cows had been overevaluated relative to bulls by MCC methodology. The SD were from 4 to 11% higher for PTA than for PD. The increased spread in PTA results from the additional information provided by relatives with the animal model system. Correlations between PD and PTA were similar for all breeds (.92 to .95). Mean REL was .13 to .17 higher than RPT. Animal model REL includes information from all relatives by summing contributions from parents, progeny, and, for cows, own yield. Bull RPT from the MCC expressed accuracy of information from daughters only, even though the sire and maternal grandsire pedigree information was included in PD. Thus, mean REL was expected to be considerably higher than mean RPT for bulls.

Changes in the measures of accuracy and evaluations are in Table 5 for Holstein bulls. Mean REL was much higher than RPT for bulls with low RPT and only slightly higher for bulls with high RPT. Differences between PTA milk and adjusted PD milk were all positive, a reflection of the relatively young ages of the bulls and the underestimation of genetic trend by MCC in addition to adjustment for the

TABLE 5. Mean reliabilities (REL) and differences and correlations between PD adjusted for genetic base change and PTA milk for Holstein bulls by repeatability (RPT).

RPT	Number of bulls	Mean REL	PTA – PD	Correlation
		(%)	(kg)	
.13 to .19	771	.39	40	.89
.20 to .29	4115	.44	55	.90
.30 to .39	1383	.54	79	.93
.40 to .49	902	.60	87	.94
.50 to .59	938	.67	109	.95
.60 to .69	1138	.73	123	.96
.70 to .79	1127	.79	113	.97
.80 to .89	404	.86	92	.98
.90 to .99	375	.97	79	.99
All	11,153	.58	79	.94

TABLE 6. Correlations between Modified Contemporary Comparison (MCC) evaluations and difference[1] between MCC and animal model evaluations.

Breed	Difference		Absolute difference	
	Bulls	Cows	Bulls	Cows
Holstein	.12**	.13**	.05**	–.07**
Jersey	.05	.11**	–.11**	.01
Guernsey	.00	.12**	–.19**	.02**
Brown Swiss	–.07	.10**	.04	–.01
Ayrshire	–.10	.04**	–.01	.00

[1]Animal evaluation minus MCC evaluation.

**$P \leq .01$.

genetic base change based on cows rather than bulls. These differences also tended to be larger at moderate RPT than at higher and lower RPT. Correlations between PTA and PD were high even for bulls with low RPT. For Holstein bulls with RPT less than .20, correlation between MCC and animal model evaluations was .89; correlation for bulls with RPT of .90 or higher was .99.

Correlations with change between MCC and animal model evaluations are in Table 6 for MCC evaluations and in Table 7 for MCC RPT. Evaluations of high CI cows tended to improve in all breeds (Table 6). A similar condition for bulls was present only for Holsteins. Correlations between MCC evaluations and absolute differences were both positive and negative and were near 0 for both sexes for most breeds. However, Jersey and Guernsey bulls with higher PD tended to have less change than those with lower PD. Both bulls and cows with higher RPT tended to increase in PTA compared with MCC evaluations (Table 7). The absolute difference between evaluations changed less for animals with higher RPT except for Holstein bulls. Because more information was included in MCC evaluations with high RPT, these animals would be expected to be affected less by the additional information provided with the animal model.

Characteristics of animal model and MCC cow evaluations for milk yield and their accuracy are given in Table 8 for the three data subsets by breed. Cows born in 1985 average 0 for PTA by definition of the genetic base. Because CI had been adjusted for the base change, adjusted CI also averaged 0 for cows born in 1985. However, data were only from cows with matching evaluations under both systems; therefore, some means for PTA and adjusted CI were slightly different from 0. Mean PTA milk for Holstein cows born in 1980 was 36 kg less than their mean adjusted CI milk, which suggests a higher estimate for

TABLE 7. Correlations between Modified Contemporary Comparison (MCC) repeatability and difference[1] between MCC and animal model evaluations.

Breed	Difference		Absolute difference	
	Bulls	Cows	Bulls	Cows
Holstein	.21**	.21**	.09**	–.17**
Jersey	.07*	.04**	–.23**	–.05**
Guernsey	.23**	.10**	–.32**	–.05**
Brown Swiss	.12	.08**	–.23**	–.10**
Ayrshire	.10	–.02	–.26**	–.05**

[1]Animal evaluation minus MCC evaluation.

*$P \leq .05$.

**$P \leq .01$.

TABLE 8. Means and SD for Cow Index (CI) milk adjusted for genetic base change and cow PTA milk, correlations between adjusted CI and PTA, and mean repeatabilities (RPT) and reliabilities (REL) for three data sets by breed.

Breed	Data set	Number of cows	Adjusted CI milk		PTA Milk		Correlation	Mean RPT	Mean REL
			(kg)						
			$\overline{X}$	SD	$\overline{X}$	SD			
Holstein	Born 1980	590,961	−229	200	−265	235	.91	.42	.47
	Born 1985	576,753	0	213	0	240	.94	.39	.42
	Top 10% for CI$[1]	27,662	+363	132	+414	161	.89	.45	.47
Jersey	Born 1980	32,540	−217	171	−198	192	.93	.43	.48
	Born 1985	31,807	0	172	0	191	.96	.40	.43
	Top 10% for CI$	10,434	+240	90	+266	115	.87	.45	.47
Guernsey	Born 1980	15,134	−186	151	−188	174	.92	.42	.46
	Born 1985	11,055	0	150	0	166	.94	.38	.42
	Top 10% for CI$	3163	+236	85	+261	113	.84	.44	.47
Brown Swiss	Born 1980	8118	−224	189	−215	218	.91	.41	.46
	Born 1985	5965	+1	176	−4	198	.92	.37	.41
	Top 10% for CI$	2272	+257	90	+276	127	.79	.44	.47
Ayrshire	Born 1980	5952	−106	150	−112	169	.90	.41	.45
	Born 1985	4084	+1	142	−2	159	.92	.36	.40
	Top 10% for CI$	1395	+237	77	+261	113	.78	.43	.46

[1]Meets all requirements for January 1989 Modified Contemporary Comparison elite status except that minimum CI dollars (CI$) was lowered to include 10% of eligible cows. Only cows born in 1980 or 1985 were included for Holsteins.

genetic trend with the animal model than with MCC. Animal model trends for 1980 through 1985 also were slightly higher than MCC trends for Ayrshires but were lower for Jerseys and Brown Swiss and nearly equal for Guernseys. Because of these differences in trend between the two evaluation systems, differences between MCC and animal model evaluations generally would be larger for earlier years even with adjustment for the genetic base change.

Mean Holstein cow PTA increased by 265 kg milk from 1980 to 1985, which suggests annual genetic trend in breeding value for milk yield of 106 kg under the animal model. Estimates of annual trend for other breeds were substantial but lower (85 kg for Brown Swiss, 79 kg for Jerseys, 75 kg for Guernseys, and 44 kg for Ayrshires). Current trend in breeding value for milk for Holsteins from animal model evaluations is approximately 120 kg/yr (6).

Cows among the top 10% for CI$ in January 1989 MCC evaluations tended to increase in evaluation with the animal model. That increase may be partially a response to inclusion of daughter data. High ranking cows tend to have daughters with biased deviations (7).

The SD for animal model evaluations were higher than for those for MCC evaluations. For Holsteins, SD were 13% higher for cows born in 1985 and 18% higher for cows born in 1980. Increased SD for cows resulted partly from changing heritability of milk yield from 20 to 25%.

Correlations between CI and PTA for cows born in 1980 (.90 to .93) were lower than for cows born in 1985 (.92 to .96) because of the opportunity for daughters to affect their evaluations. Cow PTA also are influenced by son PTA, but impact from sons would be minimal (if any) for cows born as recently as 1980.

Cow REL generally were .02 to .05 higher than RPT. With MCC, cow RPT included parents and own yield but not progeny. Increases in measure of accuracy were greater for older than for younger cows because of the opportunity for contribution from progeny with the animal model.

Daughter equivalent is a measure of information in unit equivalent to that from a single-record daughter in a large herd (10). Mean PTA milk and differences between PTA and

TABLE 9. Mean PTA milk and differences between PTA milk and Cow Index (CI) milk[1] and between reliability (REL) and repeatability (RPT) for cows born in 1980 according to breed and number of progeny daughter equivalents (DE) and breed.

Breed	Progeny DE	Number of cows	PTA	PTA − CI	REL − RPT
			(kg)		
Holstein	0	362,851	−291	−49	.032
	1	147,317	−241	−24	.053
	2	53,489	−207	−11	.065
	3	21,095	−180	4	.078
	4	5068	−154	15	.090
	5	880	−96	27	.101
	6	145	−27	29	.111
	7	44	+149	31	.121
	8	19	+276	60	.126
	9	13	+278	43	.143
	≥10	40	+352	34	.175
Jersey	0	17,862	−219	14	.033
	1	8749	−190	19	.054
	2	3671	−158	30	.067
	3	1644	−142	37	.080
	4	495	−111	46	.092
	5	101	−41	+68	.105
	6	11	+20	154	.108
	≥7	7	+193	91	.127
Guernsey	0	9240	−199	−5	.035
	1	4127	−181	−2	.056
	2	1301	−148	14	.069
	3	377	−125	20	.082
	4	75	−125	20	.104
	≥5	14	−125	20	.106
Brown Swiss	0	5276	−237	5	.034
	1	2044	−192	8	.053
	2	569	−143	28	.067
	3	188	−120	43	.078
	4	35	−29	80	.095
	≥5	6	+142	212	.107
Ayrshire	0	3805	−124	−8	.035
	1	1530	−99	−6	.056
	2	448	−65	8	.072
	3	129	−74	13	.085
	4	36	−66	7	.094
	≥5	4	+29	42	.113

[1]Cow Index adjusted for base change.

CI and between REL and RPT for cows born in 1980 are in Table 9 according to breed and the number of DE from progeny. Cows with more DE (calculated from progeny only) had higher CI and higher PTA and generally showed a larger increase from CI to PTA. Even more dramatic was the increase from RPT to REL as number of progeny DE increased. With no progeny, mean REL was .032 to .035 higher than mean RPT. This small increase was attributed to the increase in heritability for female milk yield evaluations and to the higher parent REL than under MCC. With high progeny DE, REL were increased substantially. Holstein cows with 10 or more progeny DE averaged 68% REL but only 50% RPT.

CONCLUSIONS

Requiring first lactation records for animal model evaluations minimized potential problems due to selection bias but also reduced number of cows with information included compared with MCC evaluations. Definitions chosen for animal model management groups resulted in smaller and more uniform comparison groups than MCC modified contemporary groups.

Differences between animal model and MCC evaluations generally were as expected and consistent with the animal model's use of additional relative information. Effects of base change differed by birth year, breed, and sex. Increases in animal model evaluations from MCC evaluations tended to be greater for bulls and cows with higher RPT, higher PD Holstein bulls and younger Holstein cows, higher CI cows, and cows with more progeny. As expected from including more information in evaluations, animal model evaluations had a larger SD than MCC evaluations. Correlations were high between MCC and animal model evaluations for both bulls and cows of all breeds. For bulls, correlations were from .92 to .95 depending on breed and were as high as .99 for high RPT Holstein bulls.

Animal model REL were higher than MCC RPT because all relatives contribute to each PTA. Increase in REL from RPT was much greater for low RPT bulls because ancestor information previously used in evaluations also is reflected in REL now. For cows, increase in REL from RPT increased as number of evaluated progeny increased.

The MCC has been an effective genetic evaluation tool as indicated by high rates of genetic improvement. However, based on animal model results, the MCC underestimated rate of progress for Holsteins. The animal model system uses available information more completely, and VanRaden et al. (8) found that the animal model was superior to MCC by 3 to 5% in 3 of 4 pathways in ability to predict merit of future sons and daughters. Therefore, future genetic progress should be more rapid with selection decisions based on animal model evaluations.

ACKNOWLEDGMENTS

The assistance of S. M. Hubbard of the Animal Improvement Programs Laboratory, ARS, USDA, Beltsville, MD in manuscript review is appreciated greatly. Suggestions for manuscript improvement by A. W. Norman and C. W. Wolfe, American Jersey Cattle Club, Reynoldsburg, OH also are acknowledged. The cooperation of the US dairy industry in supplying yield and pedigree data through the National Cooperative DHI Program is appreciated.

REFERENCES

1 Dickinson, F. N. 1985. USDA-DHIA sire summaries for yield traits: data sources and summary requirements. Natl. Coop. DHI Program Handbook, Fact Sheet H-3, Washington, DC.

2 Dickinson, F. N., H. D. Norman, R. L. Powell, L. G. Waite, and B. T. McDaniel. 1976. Procedures used to calculate the USDA-DHIA Modified Contemporary Comparison. Page 18 *in* USDA Prod. Res. Rep. No. 165, Washington, DC.

3 Norman, H. D. 1986. Sire evaluation procedures for yield traits. Natl. Coop. DHI Program Handbook, Fact Sheet H-1, Washington, DC.

4 Norman, H. D., G. R. Wiggans, C. A. Ernst, and J. R. Wright. 1989. Determination of size of management group for optimizing predictability in the animal model. J. Dairy Sci. 72 (J. Anim. Sci. 67) (Suppl. 1): 71.(Abstr.)

5 Powell, R. L. 1985. Elite Cow Index. Natl. Coop. DHI Program Handbook, Fact Sheet H-4, Washington, DC.

6 Powell, R. L. 1990. U.S. genetic progress contributes to world genetics. Hoard's Dairyman 135:507.

7 Powell, R. L., and H. D. Norman. 1988. Accuracy of cow indexes according to repeatability, evaluation, herd yield, and registry status. J. Dairy Sci. 71:2232.

8 VanRaden, P. M., C. A. Ernst, and G. R. Wiggans. 1989. Ability of animal model and Modified Contemporary Comparison evaluations of parents to predict future progeny performance. J. Dairy Sci. 72(Suppl. 1):72.(Abstr.)

9 Wiggans, G. R., I. Misztal, and L. D. Van Vleck. 1988. Implementation of an animal model for genetic evaluation of dairy cattle in the United States. J. Dairy Sci. 71(Suppl. 2):54.

10 Wiggans, G. R., and P. M. VanRaden. 1989. USDA-DHIA animal model genetic evaluations. Natl. Coop. DHI Program Handbook, Fact Sheet H-2, Washington, DC.