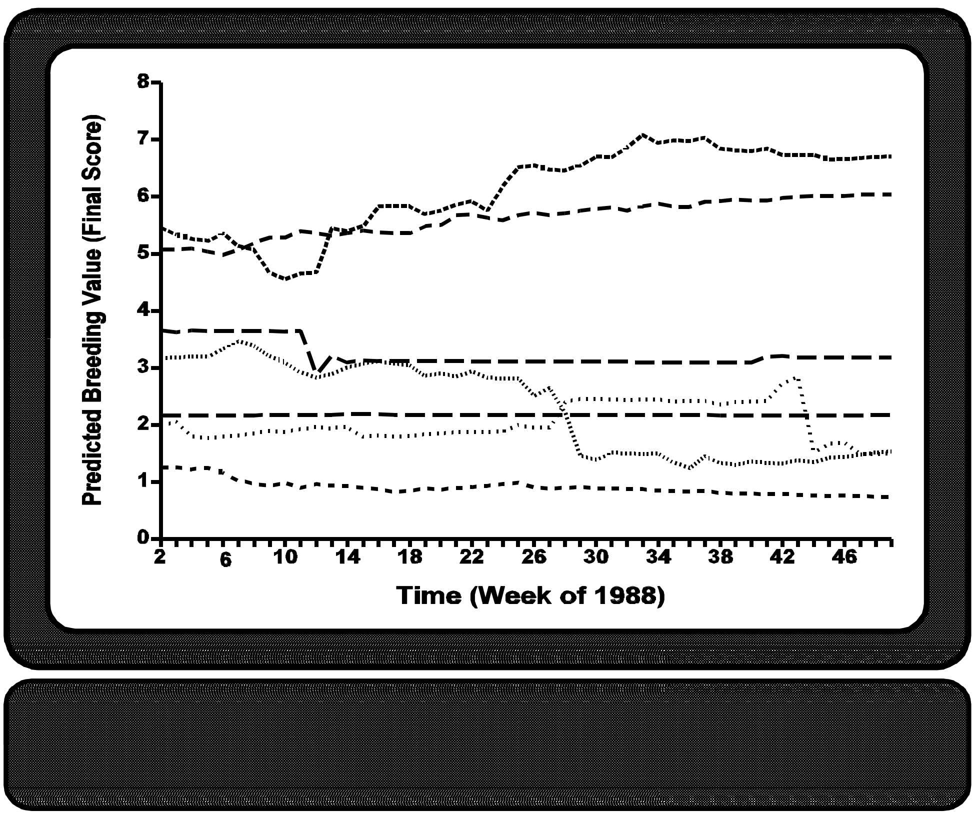
PROCEEDINGS OF THE SYMPOSIUM ON CONTINUOUS EVALUATION IN DAIRY CATTLE



College Park, MD • June 13, 1993

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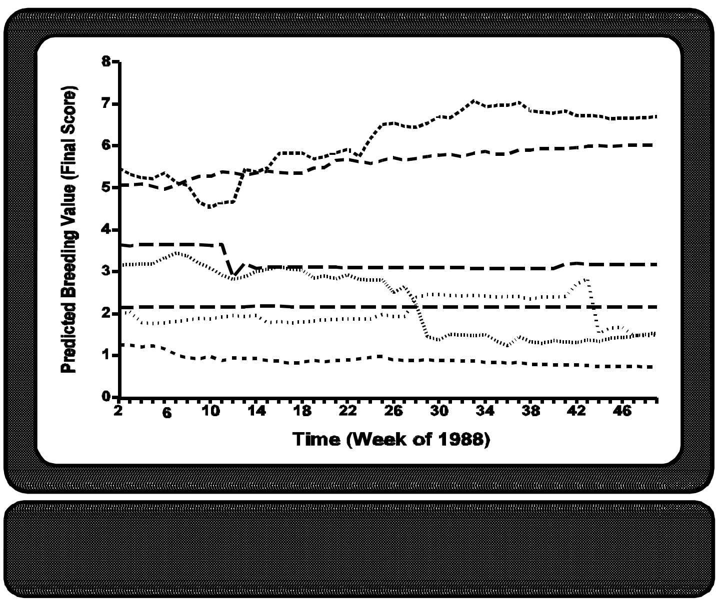

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[1]Peer-reviewed.
[2]Reprinted from the *Journal of Dairy Science* (74:2001; 1991).

Introduction

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Currently in the US, new records are incorporated into semiannual genetic evaluations 2 to 8 mo after they become available. Thus, the most current information is underutilized. Because of advances in computer and telecommunications technology, it now is technically feasible to create a continuous evaluation (**CE**) system. Ideally, such a system would always be accessible to receive new records, resulting in continuous incorporation into evaluations. The most current evaluations would be available for distribution electronically. The CE system would use the data more effectively, and additional computing cost would be small compared with the cost of data collection.

A CE system has both advantages and disadvantages. The dairy industry could be provided with more timely and accurate genetic information, leading to better selection of animals, particularly for young sires and elite bull-dams. In the future, CE could provide a platform for more sophisticated mating programs, where inbreeding or even marker information is considered. However, CE also could cause difficulties, such as information overload, unforeseen extra costs, or new opportunities for misleading advertising.

Many questions remain to be solved before CE is implemented. What is the average financial gain per cow or bull? How will the gains be distributed among various sectors of the industry? What is the cost of setting up and operating the system? Will farmers, who support data recording, be willing to support CE? What information should be released? Should information from past periods be included? Should thresholds be set for evaluation changes to minimize the number of evaluations released with small, short-term changes?

The purpose of the symposium is to bring together all sectors of the industry involved in the genetic evaluation of dairy cattle, to identify problems and opportunities of CE, and to propose possible solutions. Lohuis et al. examine the theoretical gains of CE, which could potentially be as much as 9% greater genetic progress or an extra $15 profit per cow. Wiggans and VanRaden present the data flow in evaluation of yield traits and USDA evaluation technology. If computer tapes were the main information carriers, one evaluation cycle would take a minimum of 6 wk, including only 1 wk in calculating animal model solutions. Misztal elaborates on the implementation strategy for CE. By exploiting computer downsizing in the industry, CE could be implemented without large investments. Lawlor et al. look at the data flow of type information and examine the attitudes of dairy farmers. Type information on Holstein cattle is now being collected and sent back to the industry electronically. Most of polled dairy producers were ready for more frequent evaluations. Hoyt evaluates CE from the perspective of the AI industry. Some AI organizations feel that CE will bring few (if any) genetic benefits, confuse the industry, and destroy current marketing plans of AI organizations. A different impact on AI organizations is reported by Miller, where CE could simplify selection of bulls and bull-dams and required changes in marketing would be manageable. According to Welper, AI may gain from CE both genetically and financially, and CE could help the US dairy industry keep its competitive advantage. Funk looks at the attitude of commercial dairy producers. The dairy producers will likely adapt to more frequent evaluations, but a convenient delivery system for the genetic information needs to be developed. Jensen describes the evaluation system in Denmark, which is characterized by frequent evaluations (mostly monthly) of many traits and the testing of many bulls. The Danish cattle industry is, by tradition, used to frequent evaluations and will not accept more infrequent dissemination of updated information.

A reprint of the article "Continuous Genetic Evaluation of Holsteins for Type" by Misztal et al. has been included as a reference. This study, the first to investigate CE, shows weekly evaluations for selected animals and discusses various issues in CE modeling and computing.

Abbreviation key: CE = continuous genetic evaluation

The Effect of Continuous Evaluation on Genetic Response in Progeny Test Programs

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ABSTRACT

The Canadian dairy population of 1.2M cows is modelled to determine the extra genetic response from changing from standard (semi-annual) to continuous genetic evaluation. Selection for maximum estimated breeding value was truncated across mature age categories in traditional schemes and across all age categories in modern schemes. Deterministic formulas were used to predict rates of genetic response and inbreeding. Adjustments were made to account for effects of selection, inbreeding, and between age class variance on genetic variance and accuracy of selection, and for effects of correlated estimated breeding values within age classes, and finite population size on selection intensities.

If continuous evaluation is implemented in all paths, 7 to 9% higher rates of annual genetic response is predicted. Most of the expected superiority is established after one generation and continues in subsequent generations. In general, most of the advantage of CE is caused by lower generation intervals without a substantial reduction in accuracy on selected animals. By implementing CE for one year, the present value of extra profits to dairy farmers, accumulated over a 25 year planning horizon, would equal $13 to $20 for each cow in the population. The proportion of dams of AI bulls selected from first-lactation females increased from 5% to 41% with continuous evaluation. Implementation of CE in the dams of sires pathway produced the greatest improvement in genetic response.

(**Keywords:** continuous genetic evaluation, progeny testing, partial records, BLUP)

Abbreviation key:

CE = continuous genetic evaluation

DD = dams of dams

DS = dams of sires

EBV = estimated breeding value

M = modern scheme

PT = progeny test

SD = sires of dams

SE = standard genetic evaluation

SS = sires of sires

T = traditional scheme

INTRODUCTION

Progeny test (**PT**) programs for dairy cattle have operated effectively in many countries for decades. Genetic evaluation programs have increased in sophistication and accuracy, as methods such as contemporary comparison were replaced by sire models and eventually animal models with BLUP properties (10). Genetic progress for production traits has accelerated recently in a number of countries, leading to international competition between populations. Current methods of evaluation typically involve semi-annual assimilation of field data into a national database followed by execution of national BLUP animal model evaluations. Results are distributed electronically as well as by mail.

Continuous genetic evaluation (**CE**) is a technique currently being examined for its potential to further improve rates of genetic response through reducing delays between data collection and availability of genetic evaluations. Smith and Burnside (24) suggested that these delays could add 10 to 15% to the generation interval and decrease annual response by a similar percentage. Direct updating of bull and cow evaluations was implemented in Denmark in 1986, following a selection index approach outlined by Christensen (4). In this approach, breeding values can be updated each time new information is added. Usually, this would be done each time a herd is milk recorded. It is also possible to account for common environmental effects and heterogeneous herd variance and heritability.

With improvements in communication and computing technology, various methods have now been suggested to update animal model evaluations with new data (11, 17, 23, 29). For example, prior information on national solutions for animal genetic effects could be incorporated into mixed model equations for within herd data. The number of equations would be relatively small, and within-herd evaluations could be performed easily at milk-recording centres or perhaps even at the farm. Other methods involve continuously adding new data to national evaluations and continuing to iterate until solutions stabilize. The use of a test-day model rather than the 305-day model has also suggested possible improvement in accuracy and reduction in cost (12, 18, 19, 26). Test-day models can account for fixed effects associated directly with the day of test. These two changes may complement each other, if implemented in concert, since lactation extension factors could be eliminated and fewer tests may be needed per lactation. On its own, CE could, nevertheless, have a sizeable impact in reducing generation interval without substantially affecting average accuracy of selection.

In order to maximize benefit from CE, both implementation and application considerations must be addressed. CE could be implemented in selected pathways, such as those used in sire procurement. Alternatively, CE could be offered to some sectors of the industry that would be open to new technologies and for whom implementation would be cost-effective. To determine the optimum extent of implementation, potential improvement in the four genetic pathways must be quantified and weighed against the cost and problems associated with each. Also, CE must be readily available to the end-user in a credible and dependable format to ensure that application takes place. The purpose of this paper is to quantify the benefits of CE in terms of increased genetic response and determine which genetic pathways receive the most benefit. Effects on inbreeding rate, genetic variance, accuracy and generation interval will also be discussed. The sensitivity of the results to some of the assumptions made in this research will also be dealt with.

MATERIAL AND METHODS

The Model

There are two approaches to modelling the effect of CE on the rate of genetic response in dairy cattle. One method would involve an exact simulation of the standard evaluation (**SE**) process and comparing it to the CE process. In a deterministic simulation, this would involve dividing the population into very small segments and performing selection across all of them. Doing this, however, would pose problems in computing accurate selection intensities for each segment and making various adjustments to account for the effects of selection and inbreeding. Monte Carlo simulations are an alternative, but require larger computing resources and are less flexible to changes in parameters. This study followed a deterministic approach but modelled the evaluation process indirectly through the effects of SE and CE on generation interval, accuracy, genetic variance, and selection intensity. The sire evaluation process was modelled by maintaining the same accuracy, in a given age group, for SE and CE, only changing the delay between data availability and genetic evaluation. Modelling female evaluation required a different approach because breeding decisions are usually only made in the first few months of lactation. In this case, the generation interval was held constant, for a given age group, but the accuracy at the time of breeding was modified for the two evaluation methods.

The model employs deterministic formulas to simulate the Canadian breeding population of 1.2M breeding age females and 400 young sires progeny tested each year. Parameters used for selection are given in Table 1.

Table 1 Parameters for selection in traditional (T) and modern (M) progeny test schemes [1]

	Pathway [2]			
Parameter	SS	SD	DS	DD
Total number [3]	3630	3630	1,200,000	1,200,000
Traditional (T) scheme:				
Age groups available	5 to 10	5 to 10	3 to 10	1 to 10
Number available	1726	1726	396,000	876,500
Number selected [4]	33	100	800	788,850
Proportion selected	0.0197	0.0579	0.0020	0.9000
Modern (M) scheme:				
Age groups available	1 to 10	1 to 10	1 to 10	1 to 10
Number available	3210	3210	876,500	876,500
Number selected [4]	33	100	800	788,850
Proportion selected	0.0103	0.0312	0.0009	0.9000

[1] Both schemes involves progeny testing 400 young sires per year and an annual random loss of 0.05 for males and a typical age distribution of females (14). Selection is on a total merit trait with a heritability of 0.30.
[2] SS = sires of sires, SD = sires of dams, DS = dams of sires and DD = dams of dams.
[3] Total number is the number of animals in all age groups (0 to 10).
[4] The number and proportion selected were taken from Canadian and U.S. industry standards (27; Canadian Genetic Evaluation Board Release, 1992).

Details of the method are given in Lohuis et. al. (14), but will be summarized briefly here. Male and female populations were divided into eleven yearly groups, with each year group divided into two six-month age categories. A typical age distribution of females (15) and an annual random loss of 5% of sires were assumed. The oldest age group was assumed to be eleven years of age. It was assumed in this study that females were culled involuntarily for reasons including reproduction, health, and other management problems. Selection was on a total merit index with a base population heritability of 0.30. Truncation selection on estimated breeding value (**EBV**) (EBV = 2 x estimated transmitting ability) was practised in four pathways of selection: sires of sires (**SS**), sires of dams (**SD**), dams of sires (**DS**) and dams of dams (**DD**). Differences in genetic means (**μ**) between age categories were derived from the rate of genetic response occurring in the previous generation. Optimised selection across all available age categories was performed using the algorithm outlined by Ducrocq and Quaas (7), in which genetic merit of parents is maximised by truncation selection of the highest EBV from all age categories. After selection, rate of genetic response and genetic variances in the male and female populations were re-calculated and used in the next iteration of the model. Each iteration approximated one generation of selection.

To arrive at a starting point for alternative schemes, a traditional PT with SE was assumed for the population. Without adjustments for inbreeding, this population remained under constant selection until asymptotes were approached for sire variance, dam variance and annual genetic response. The convergence criterion was 1×10^{-4} genetic s.d. units. Convergence was reached in under 10 cycles of selection.

Both traditional (**T**) and modern (**M**) PT schemes, are used for comparisons between SE and CE. The T scheme involves selection of only milking females as bull dams and males with a progeny test as sires of cows and sires of sons. The M scheme considers all post-pubertal age categories for selection for both sires and dams. In both schemes, it was assumed that one-quarter of the female population were bred to unproven young sires for progeny testing purposes. SE was defined as a national BLUP animal model evaluation done on a semi-annual basis, whereas CE involves continuous updating of a national database and continuous (or very frequent) computing of BLUP animal model solutions. The model used to approximate SE and CE, in fact, models the effect of the two evaluation systems on generation interval, accuracy, selection intensity, and genetic variance. The assumptions used are given in Table 2.

Table 2 A description of standard (SE) and continuous evaluations (CE) [1]

	Standard	Continuous
Information for males: [2]		
complete records only	A and B	A and B
complete and/or part records [3]	C, D, E	C, D, E
delay [4]	5 months	2 weeks
Information for females: [2]		
complete records only	A, B and F	A and B
complete and/or part records [3]	C and D	C, D and F
delay [4]	5 months	2 weeks

[1] Standard evaluation refers to national BLUP animal model evaluations conducted every 6 months. Continuous evaluations are standard evaluations continuously updated.
[2] Information sources:
A - Maternal grandsire: 200 daughters, 2 to 3 records
B - Maternal granddam: 2 to 3 records
C - Sire: 50 to 200 daughters, 1 to 3 records
D - Dam: 1 to 3 records
E - 50 to 200 Daughters: 1 to 3 records
F - Self: 1 to 8 records
[3] Part records were made up of information from the first 2 months of lactation.
[4] The delay was the average interval between data collection and dissemination of evaluations.

In semi-annual evaluations, the delay between data collection and the next evaluation varies from 0 to 6 months with a mean delay of 3 months, with the assumption that cows are not bred on a seasonal basis. It was assumed that data assimilation and computing required 1.5 months and dissemination of evaluations required 2 weeks. Therefore, the average delay between collection of data and availability of evaluations was assumed to be 5 months for SE and 2 weeks for CE (one week for computing and one week for dissemination.) The resulting difference in evaluation delay between SE and CE was 4.5 months. To test the sensitivity of these assumptions, the 1.5 month delay required for computing of SE was removed reducing the difference between evaluations to 3.0 months.

Both T and M schemes were applied in practical and efficient modes. The efficient mode assumed females first calved at 24 months and maintained a 12 month calving interval thereafter, while the first crop of daughters from PT sires calved 48 months after birth of the sire. In practical mode, six months were added to the age of parents, in each age group, at the time of selection. It was assumed that selection decisions are made with results from the most recent evaluation in mind. Scenarios involving increased SE frequency (e.g. quarterly evaluations) were not considered in this study, but it was assumed that such procedures would result in intermediate increases in rate of genetic response. Many American AI companies already perform internal evaluations 3 months after national evaluation runs.

Accuracy of Evaluation

Accuracy (**r**) of evaluation for each 6 month age category was calculated for males and females using selection index techniques to approximate those in an animal model. The assumptions and details are in the Appendix. Since extended (partial) records are presently used in SE, the same information was used to calculate sire accuracies for CE, only the evaluation delay was shortened by 4.5 months (Table 2). For the female population, it was assumed that breeding decisions were made after 2.5 months of lactation. With CE, this partial record would be included in the evaluation, but in SE (under current Canadian milk recording rules) it would not. All other information sources remained the same and the difference in evaluation delay was the same as for sires. Partial records, at 60 days in milk, were assumed to have a phenotypic and genetic correlation with complete records of 0.78 and 0.83, respectively (1), although Wilmink (28) and VanRaden et al. (25), using more precise lactation prediction methods, have reported higher correlations between 305-day yields projected or expanded from partial records and realized 305-day yields. Genetic correlations between first test day records and complete lactation records of 0.87, 0.77, and 0.84 were also reported by Pander et al. (18) for milk, fat and protein yield. It was assumed that 305 days in milk constituted a complete lactation. The variance of partial records was taken as 73% of completed records (1). Both partial and complete records were assumed to have a heritability of 0.30 and a repeatability of 0.60. From these assumptions, the phenotypic correlation can be derived (Appendix) between a complete record and a part record from a different lactation, and, in this case, had a value of 0.44. To test the sensitivity of these assumptions, the heritability of partial records were reduced by one-third (to 0.20) to determine the effect on results. As well, genetic correlations between partial and complete records were also reduced by one-third (to 0.55).

Since the population has undergone selection with animals ranked by a BLUP animal model, r was adjusted for loss of variance due to selection following Dekkers (6) as:

$$r^{*} = \sqrt{1 - (1 - r^{2})\sigma_0^{2} / \sigma^{*2}} \qquad [1]$$

where σ_0^2 is the genetic variance in the unselected population and σ^{*2} is the present genetic variance. Standard deviations of EBV (σ^{*}_{EBV}) were then calculated as $r^{*}\sigma^{*}$ for each age category.

Genetic Response

Selection intensity was adjusted for finite population size according to the approximation by Burrows (3) and for correlated EBV among relatives within cohorts according to the approximation by Rawlings (20) revised by Meuwissen (16). Variance was adjusted for the effects of selection, inbreeding, and differences in selected means from different age categories (14). The inbreeding coefficient in the starting population was taken as 0.034 for the North-American Holstein population (30). Loss of variance due to inbreeding was accounted for, but no adjustments were made for inbreeding depression.

Genetic response per generation, after all adjustments, was calculated across all pathways according to standard procedures (21).

$$R^* = \sum_{j=1}^{4} .25 \left[\sum_{i=1}^{m} (w_{ij}\, I^*_{ij}\, r^*_{ij}) \right] \sigma^*_j \qquad [2]$$

where m is the number of age categories, and w_{ij} is the proportion of selected animals originating from the ith age category in the jth pathway. I^*_j is the selection intensity, adjusted for correlated breeding values and finite population size, and r^*_j and σ^*_j are the accuracy and genetic standard deviation, in path j, adjusted for selection and inbreeding. The rate and coefficient of inbreeding was calculated from the effective number of sires and dams following Falconer (8). The effective number of parents was approximated from the number of parents selected and the average selection intensity and intra-class correlation between EBV (22). For the SS and SD pathways, $\sigma^*_j = \sigma^*_S$, and for the DS and DD pathways, $\sigma^*_j = \sigma^*_D$. In the SD pathway, I^*_j was adjusted for the proportion of females sired by untested young sires ($\mathbf{P_{YS}}$), for which selection intensity is zero, as $I^*_j(1 - P_{YS})$.

Annual genetic response was then calculated as:

$$\Delta G = R^* / \left[\sum_{j=1}^{4} .25 \left(\sum_{i=1}^{m} w_{ij}\, L_{ij} \right) \right] \qquad [3]$$

where L_{ij} is the generation interval of the ith age category in the jth pathway.

Annual genetic responses were calculated for T and M schemes with SE and with CE. Both practical and efficient modes of selection were considered. Since national breeding strategy normally involves a longer planning horizon than corporate strategy, annual genetic responses were calculated over 5 cycles of selection (approximately

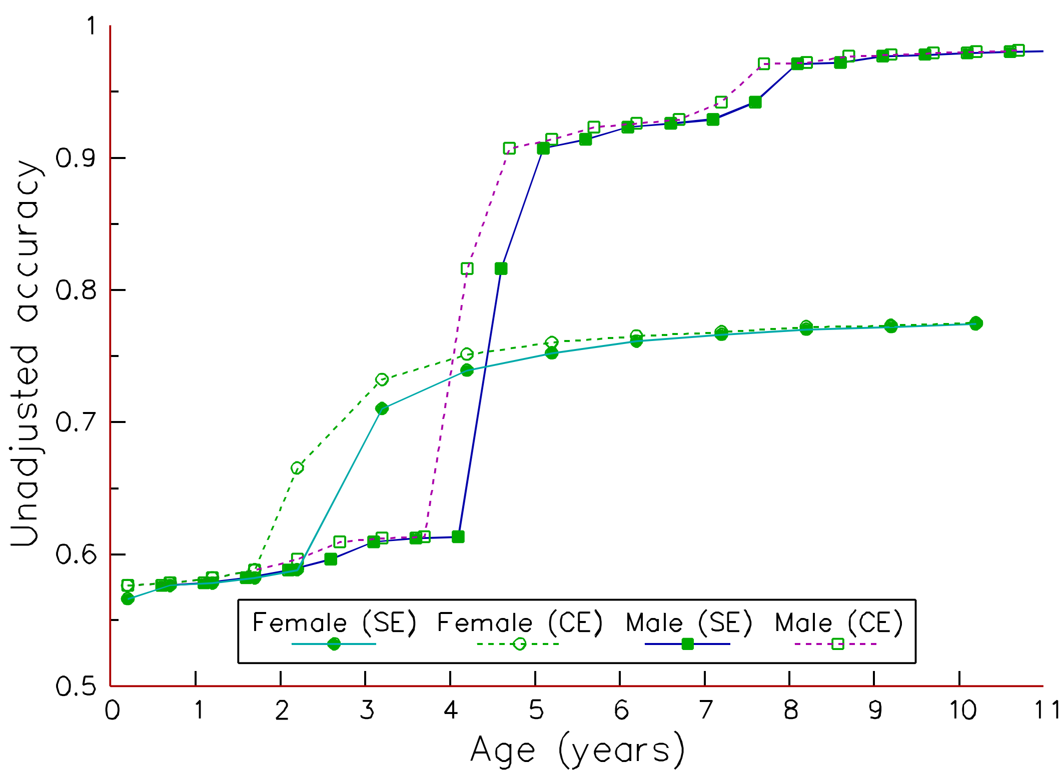

Figure 1 Accuracies (unadjusted for selection) for males (closed squares) and females (closed circles) with standard evaluation (SE), or for males (open squares) and females (open circles) with continuous evaluation (CE)

5 generations) starting from a T scheme with SE. To determine which pathways were affected most by CE, each pathway was changed from SE to CE independently and in combination with one other pathway.

RESULTS

Accuracy of Age Categories

The resulting unadjusted accuracies for males and females, in efficient selection mode, with SE and CE are shown in Figure 1. In the female population, the largest difference between CE and SE occurs at 2.2 years of age when partial lactation records become available with CE, and unadjusted accuracy is 13% higher than with SE. Accuracies adjusted for the effects of selection are 22% higher with CE. This difference diminishes quickly in subsequent lactations when complete lactation information becomes available. In the male population, the only difference is the delay between data collection and dissemination of evaluations. Therefore, the difference appears in Figure 1 as a 4.5 month shift. The largest difference in accuracy (33% higher) occurs at 4.2 years of age when partial records become available from the daughters with CE. Accuracies, adjusted for the effects of selection, are up to 74% higher for CE at this age. This difference disappears within one year, but a small difference of 3% (5% when adjusted for selection) reappears between years 7 and 8 when the second crop of daughters begin milking. However, since younger age groups were selected under CE, the net effect on accuracy was very small. The average adjusted accuracy of all animals selected as parents changed by less than a factor of 0.02 and, in most cases, it increased. Because the effect on average accuracy was negligible, the error of prediction associated with SE and CE differs very little. Therefore, the most advantageous scheme will be the one that shows the highest genetic response as estimated from deterministic simulation (hereafter referred to as genetic response.) It should be noted that although genetic response estimated by deterministic simulations quite often overestimates the actual genetic response, the comparison between schemes is likely more accurate and of greater importance.

Genetic Response

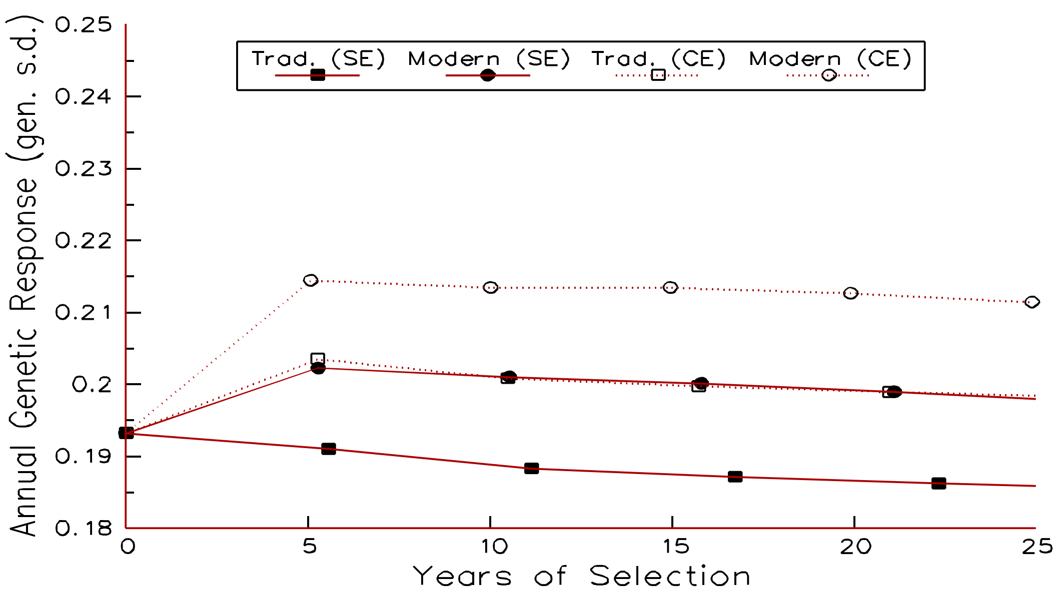

Figure 2 Annual genetic response for traditional (T) and modern (M) schemes with continuous (CE) and standard (SE) evaluations in practical mode

The effects of CE on annual genetic response for T and M schemes can be seen in Figure 2, for practical mode, and in Figure 3 for efficient mode. Since the different schemes vary in regards to generation length, the annual genetic response is plotted against years of selection rather than cycles (generations) of selection. The starting values for all schemes were those from the T scheme, with SE, at equilibrium. Equilibrium was reached in under 10 cycles of selection for both practical and efficient modes. Due to the loss of variance from inbreeding, the T scheme with SE gradually declines, but with CE there is an initial increase in annual response of 6.6 and 7.3% followed by a gradual decline. Most of the advantage over SE is established in the first generation but the relative advantage continues in subsequent generations. When a M scheme begins with SE, the initial advantage is similar to that observed from the T scheme with CE. In practical mode, this relationship holds in subsequent generations, but in efficient mode (Figure 3), the advantage of scheme M increases. The reason is that when the annual response is high enough, in a modern scheme, the relative advantage and contribution of younger age categories increases. When greater numbers of parents come from younger age categories, the selection intensity rises and the between-group variance increases and adds to the genetic variance. In efficient mode, this additional variance more than compensates for the variance lost due to inbreeding and selection. However, the inbreeding level will eventually increase to the point where variance and annual response start to decrease (generation 6). The largest annual response is achieved from the M scheme using

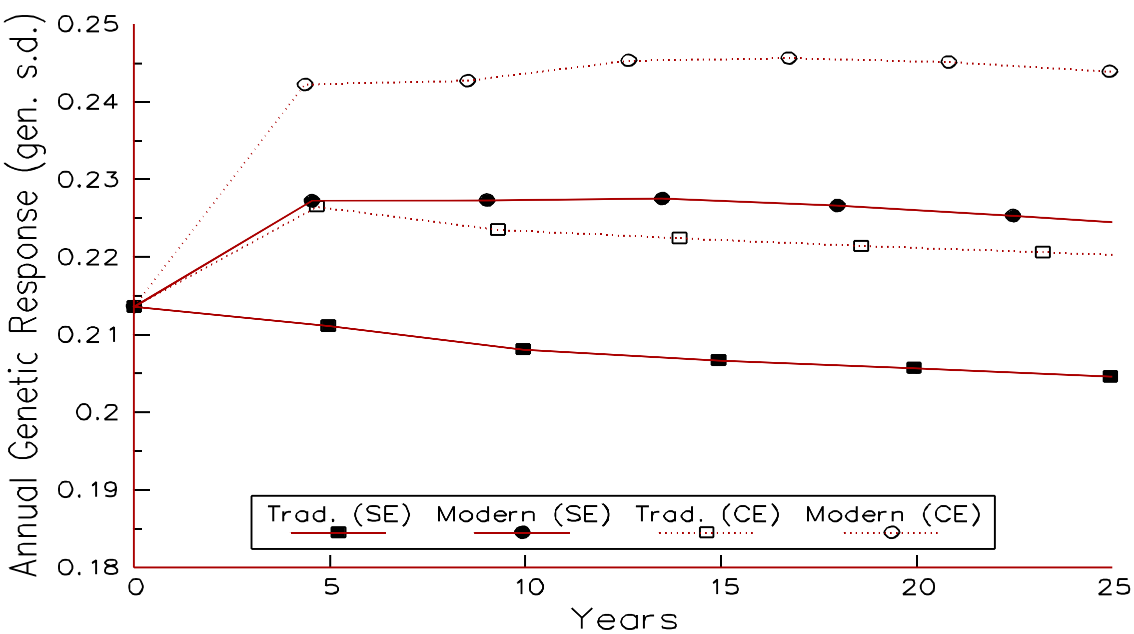

Figure 3 Annual genetic response for traditional (T) and modern (M) schemes with continuous (CE) and standard (SE) evaluations in efficient mode

CE.

Table 3 Annual genetic response (ÄG), after 5 generations, generation interval (L), annual inbreeding rate (ÄF), and genetic variance of sires and dams for practical schemes [1]

	Traditional PT		Modern PT	
	Standard	Continuous [2]	Standard	Continuous [2]
ÄG [3]	0.186	(1.068)	0.198	(1.070)
L_{AVG}	5.605	(0.936)	5.343	(0.932)
ÄF x 1000	0.762	(1.070)	0.802	(1.072)
ó$_{S}^{2}$ [3]	0.661	(1.005)	0.670	(1.000)
ó$_{D}^{2}$ [3]	0.764	(1.002)	0.783	(1.010)
SS pathway:				
r_{TI}	0.857	(0.997)	0.857	(0.992)
L	7.253	(0.941)	7.206	(0.928)
W_{4+}	1.000	1.000	1.000	1.000
SD pathway: [4]				
r_{TI}	0.862	(0.995)	0.778	(0.929)
L	6.035	(0.938)	5.574	(0.894)
W_{4+}	1.000	1.000	0.882	0.810
DS pathway:				
r_{TI}	0.603	(0.981)	0.572	(1.030)
L	4.979	(0.871)	4.445	(0.923)
W_1	-	-	0.195	0.095
W_2	0.051	0.413	0.049	0.398
W_3	0.577	0.401	0.477	0.358
W_{4+}	0.372	0.187	0.280	0.150
DD pathway:				
r_{TI}	0.450	(1.100)	0.457	(1.090)
L	4.151	(1.000)	4.147	(1.001)

[1] Adjusted accuracy (r_{TI}), generation interval (L), and age category contributions (W_i) are given for each genetic pathway: SS=sires of sires, SD=sires of dams, DS=dams of sires, DD=dams of dams. Contributions to the DD path were not affected and not shown.
[2] Values in brackets are expressed as a proportion of those for standard evaluations.
[3] Annual genetic response and genetic variances for sires (ó$_{S}^{2}$) and dams (ó$_{D}^{2}$) are given in base population genetic s.d. units.
[4] The SD pathway values do not include 25% young sire usage.

Table 4 Annual genetic response (ÄG), after 5 generations, generation interval (L), annual inbreeding rate (ÄF), and genetic variance of sires and dams for efficient schemes [1]

	Traditional PT		Modern PT	
	Standard	Continuous [2]	Standard	Continuous [2]
ÄG [3]	0.205	(1.078)	0.225	(1.088)
L_{AVG}	5.024	(0.925)	4.495	(0.910)
ÄF x 1000	0.850	(1.081)	0.953	(1.105)
ó$_S^2$ [3]	0.663	(1.006)	0.679	(1.007)
ó$_D^2$ [3]	0.768	(1.004)	0.811	(1.018)
SS pathway:				
r_{TI}	0.853	(0.993)	0.850	(0.945)
L	6.670	(0.922)	6.516	(0.891)
W_{4+}	1.000	1.000	1.000	0.933
SD pathway: [4]				
r_{TI}	0.856	(0.996)	0.629	(0.887)
L	5.416	(0.937)	4.238	(0.839)
W_{4+}	1.000	1.000	0.661	0.548
DS pathway:				
r_{TI}	0.599	(0.984)	0.562	(1.054)
L	4.373	(0.852)	3.591	(0.940)
W_1	-	-	0.293	0.155
W_2	0.074	0.465	0.086	0.441
W_3	0.597	0.385	0.420	0.302
W_{4+}	0.329	0.151	0.201	0.102
DD pathway:				
r_{TI}	0.453	(1.101)	0.456	(1.083)
L	3.638	(1.000)	3.634	(1.000)

[1] Adjusted accuracy (r_{TI}), generation interval (L), and age category contributions (W_i) are given for each genetic pathway: SS=sires of sires, SD=sires of dams, DS=dams of sires, DD=dams of dams. Contributions to the DD path were not affected and not shown.
[2] Values in brackets are expressed as a proportion of those for standard evaluations.
[3] Annual genetic response and genetic variance of sires (ó$_S^2$) and dams (ó$_D^2$) are given in base population genetic s.d. units.
[4] The SD pathway values do not include 25% young sire usage.

The relative advantage after 5 generations, for practical schemes, can be found in Table 3. CE results in 6.8 and 7.0% larger annual response for T and M schemes, respectively, with similar increases in rate of inbreeding. Average generation interval decreased by 6.4 and 6.8%, while genetic variances, for both sires and dams, were hardly affected. In the sire pathways, average accuracy (weighted across age categories) decreased but less than the decrease in generation interval. In the DS pathway, generation interval decreased 8 to 13% with little change in accuracy. In the DD pathway, accuracy was increased 9 to 10% with no effect on generation interval. In general, most of the advantage of CE is caused by lower generation intervals without a substantial reduction in accuracy. In all but the SS pathway, juvenile categories contributed more when CE was in effect. The largest change in selection was in the DS pathway. Females between 2 and 3 years of age produced 5% of bulls for AI with SE, but this increased to 41 and 40% with CE, for T and M schemes, respectively. This was mostly due to the availability of evaluations based on partial records before the female was re-bred.

When these schemes were considered in efficient mode (Table 4), CE lead to slightly greater increases in genetic response (7.8 and 8.8%) for T and M schemes. However, the rate of inbreeding increased faster than genetic response when CE was implemented. In this type of scheme, inbreeding rates were quite low so this would likely not pose a problem. Selection of parents from various age categories followed the same pattern found in practical mode, but a greater proportion of juveniles were selected. In the M scheme, the proportion of juvenile bulls used as SS climbed to almost 7% and the proportion used as SD (outside of progeny testing) reached over 45% for CE.

Rates of genetic response and inbreeding relative to the T scheme with SE are given for all schemes in Table 5, after 1 and 5 generations. The table illustrates that by changing to CE and the M scheme simultaneously, annual response increased 14 and 20% by generation 5 for practical and efficient modes, respectively. In the efficient mode, however, inbreeding rate increased by 24%. When in efficient mode, the rate of inbreeding was increased more by a change to an M scheme than a change to CE.

Table 5 Annual genetic response and inbreeding rate (in brackets) relative to a traditional PT scheme with standard evaluations [1] after 1 and 5 generations

	Generation 1		Generation 5	
	Standard	Continuous	Standard	Continuous
Practical mode:				
Traditional PT	1.000 (1.000)	1.066 (1.057)	1.000 (1.000)	1.068 (1.070)
Modern PT	1.059 (1.057)	1.123 (1.102)	1.065 (1.052)	1.140 (1.129)
Efficient mode:				
Traditional PT	1.000 (1.000)	1.073 (1.064)	1.000 (1.000)	1.078 (1.081)
Modern PT	1.076 (1.095)	1.147 (1.142)	1.101 (1.121)	1.198 (1.239)

[1] Standard evaluations refer to national BLUP animal model evaluations conducted every 6 months. Continuous evaluations are standard evaluations continuously updated.

Table 6 Annual genetic responses for standard evaluation [1] and continuous evaluation for selected pathways after 5 generations of selection for traditional (T) and modern (M) progeny test schemes

	Standard Evaluation	Continuous evaluation in pathways [2]					
		SS	SD	DS	DD	SS + DS	All
Practical mode:							
T scheme	0.186	(1.017)	(1.013)	(1.035)	(1.001)	(1.054)	(1.068)
M scheme	0.198	(1.022)	(1.017)	(1.028)	(1.000)	(1.053)	(1.070)
Efficient mode:							
T scheme	0.205	(1.022)	(1.016)	(1.040)	(1.001)	(1.062)	(1.078)
M scheme	0.225	(1.035)	(1.027)	(1.026)	(1.000)	(1.054)	(1.088)

[1] Annual genetic responses are expressed in base population genetic s.d. units.
[2] Results for continuous evaluations (in brackets) are expressed as a proportion of values for standard evaluation.

Effect on Pathways

The effect of limiting CE to selected pathways or combinations of pathways is illustrated in Table 6. The largest improvement in annual response (4%) from CE was achieved in the DS pathway. There was a greater improvement when the T scheme was operating, because many juvenile females were already selected in M schemes. The SS pathway showed slightly more improvement from CE than the SD path. Little change resulted from changing the DD pathway to CE. However, when scheme M was in place, the relative improvement resulting from continuously evaluating sires increased. This is likely due to lower generation intervals which magnified the impact of reducing the evaluation lag by 4.5 months. If CE were available only to AI personnel for the selection of parents of bulls (SS + DS), the majority (61 to 79%) of the improvement from CE would be realized. Since the impact of these pathways is already large, this is not surprising. Very little improvement would be realized in the DD path because the selection pressure is relatively low compared to the other paths.

Sensitivity of Assumptions

In modern PT schemes, when the assumption regarding the delay between data collection and availability of SE was reduced from 4.5 to 3.0 months, the extra annual genetic response from changing to CE was reduced to 5.6 and 7.2% for practical and efficient modes, respectively. This was approximately 20% lower than the predicted extra response when normal assumptions were used (Table 7). Genetic response was moderately sensitive to this change because, even with a 3 month delay with SE, partial records were not incorporated into female evaluations. When the assumption regarding h^2 for part records was reduced from 0.30 to 0.20, the extra response from changing to CE was reduced to 5.7 and 6.7% for practical and efficient modes, respectively. When the assumption regarding the genetic correlation between partial and complete records was reduced from 0.83 to 0.55, the extra response from CE was reduced to 5.2 and 6.6%. Although h^2 and genetic correlations were reduced by 33%, the largest decrease in extra response was by 24 and 26%, respectively, because both SE and CE responses were affected. Of course, if assumptions were altered in the opposite direction, larger increases in genetic response would be expected from changing to CE.

Table 7 Sensitivity of annual genetic responses, when assumptions change, and responses relative to standard evaluations (in brackets) for modern PT schemes after 5 generations [1]

	Practical Mode		Efficient Mode	
Assumptions [2]	Standard	Continuous	Standard	Continuous
Normal assumptions	0.198 (1.000)	0.211 (1.070)	0.225 (1.000)	0.245 (1.088)
Difference in delay equals 3 months	0.200 (1.000)	0.211 (1.056)	0.229 (1.000)	0.245 (1.072)
$h^2_{part} = 0.20$	0.196 (1.000)	0.207 (1.057)	0.223 (1.000)	0.238 (1.067)
$r_G = 0.55$	0.192 (1.000)	0.202 (1.052)	0.218 (1.000)	0.2324 (1.066)

[1] Standard evaluations refer to national BLUP animal model evaluations conducted every 6 months. Continuous evaluations are standard evaluations continuously updated.
[2] The normal assumptions are those stated in the text. The other 3 scenarios test the sensitivity of the results to assumptions about evaluation delay, heritability (h^2) of partial records, and genetic correlation (r_G) between part and whole records.

DISCUSSION

In replacing SE with CE, estimated annual genetic response increased by 6.8 to 8.8% (0.013 and 0.020 genetic s.d.). In concert with optimized selection across all age categories, response was improved by up to 19.8% (0.041 genetic s.d.). It should be mentioned that if SE is improved by simply increasing the frequency of evaluations or reducing the delay between data collection and evaluation, extra response would result as well. In Canada, the expansion of partial records with less than 90 days in milk (25) would also boost the genetic response from SE. However, these improvements would not likely benefit evaluation of females because, in most cases, evaluations would still not be available when breeding decisions need to be made.

To determine the value of CE to dairy farmers, a one standard deviation of index estimated transmitting ability (sires with 50 effective daughters) was assumed to be worth $59.94 extra profit per lactating daughter, based on the present Canadian pricing scheme, in which milk price is approximately $ 0.50 (Cdn.)/L (9; Gibson, personal communication). The profit was based solely on the production components and no value was placed on type. With an accuracy of 0.907 for sires with 50 effective daughters, the value of one genetic standard deviation in the female population would, therefore, be worth ($59.94 x 2) ÷ 0.907 = $132.17. Therefore, for each year of genetic response, the annual increase in genetic response for profit from CE would be $1.72 to $2.64. Over the entire dairy industry, this benefit would be considerable. Assuming that monetary value of extra genetic improvement (**$ÄG**) only disseminates into the population 9 years later and that a time horizon of 25 years is taken, the present value future benefits (**PVFB**) of applying CE for one year can be approximated following Brascamp (2):

$$PVFB \;=\; \$\text{Ä}G \underset{t=9}{\overset{25}{\text{Ó}}} \left(\frac{1}{1+r} \right)^{t} \qquad [4]$$

where r is the discount rate (5% is assumed) and t is the year the benefit is received. In this case, using CE for one year results in a PVFB of $13.13 to $20.15 per cow. Over the Canadian dairy population of 1.2M cows this benefit would be worth $16M to $24M (Canadian). If the benefit is disseminated into the population sooner, PVFB will be greater. Considering that the annual extra cost of computing resources and staff required to carry out CE would certainly be less than $0.5M, implementing CE, at least in the SS and DS pathways, would be a sound investment. Implementing CE in the SD and DD pathways would be more costly and difficult to accomplish, because the way semen is marketed and delivered would need to be changed.

It has been shown that relatively small genetic differences between competing A.I. organizations could increase their economic returns from semen sales disproportionately (5). In the context of breeding programs competing for an international market of semen, embryos, and livestock, the advantage could be large. The benefits quantified above may be overestimated in situations where notable quantities of semen are imported from countries without CE, or where AI companies already do more frequent internal evaluations on all males and females. The benefit of CE would also be reduced if dairy farmers refuse to buy semen on a more frequent basis or are unwilling to use semen from bulls proven on the basis of partial records. However, the estimates may also underestimate the true value of CE since conservative estimates of the correlation between whole and partial records were used, and the simulation divided the lifespan of males and females into 6 month segments. In reality, CE would provide a smoother change in accuracy and likely greater differences between CE and SE. The estimates above apply primarily to production traits because the data is collected throughout a cow's lifetime. With conformation, reproduction or health traits, data is collected less frequently and the extra genetic response from CE would be less.

CE is equally important for males and females except when modern schemes are operating. The most benefit would be realized by implementation of CE in selection of sires and dams of AI bulls. However, significant benefits to dairymen may be lost if steps are not taken to implement CE in the SD path. As well, a two-tier evaluation system may not be considered equitable by cattle breeders. Certainly, implementing CE in the sires of dams path would transform the process of marketing semen. The semi-annual production of present day sire catalogues could be replaced by `electronic catalogues' for males and females. The marketing and bull purchasing `bottlenecks' at certain times of the year could be eliminated, thereby increasing efficiency. To assure easy use of CE and avoid confusion, widespread accessability of computers and appropriate software will be necessary for farmers, AI personnel and foreign buyers. One suggested method of incorporating CE into everyday farm use is to provide computer software to farmers as part of the service from milk recording organizations. This software could automatically access the results of CE from a computer bulletin board. For example, computer mating packages could make use of the latest CE results each time a breeding decision is made. The potential of integrating electronic daily milk recording information into a CE network should also be considered as a way of boosting accuracy and reducing costs.

On its own, CE would have a sizeable impact in reducing generation interval without significantly reducing average accuracy of selection. Other breeding strategies, such as the formation of centralized MOET nucleus herds, also reduce generation intervals through maximizing the impact of juvenile age categories. However, schemes that rely heavily on juvenile age categories become limited by inbreeding rather than reproductive performance when nucleus size is small (13). By incorporating CE into genetic evaluation procedures, information from the performance of individuals is used more efficiently with acceptable increases in rates of inbreeding.

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APPENDIX

The phenotype of a partial record at 60 days in milk (**P**$_{pa}$) and a complete record (**P**$_{comp}$) were defined as separate but correlated traits, as follows:

$$\mathbf{P_{pa} = G_{pa} + PE_{pa} + TE_{pa}}$$

$$\mathbf{P_{comp} = G_{pa} + G_{re} + PE_{pa} + PE_{re} + TE_{pa} + TE_{re}}$$

where G, PE and TE are genetic, permanent and temporary environmental effects, respectively, and re refers to the remaining part of the lactation. Assuming no genotype by environment interactions, the variance (**V**) **-** covariance (**COV**) structure between part and complete records from lactation a is as follows:

$$\begin{array}{c|cccccc|} & G^a_{pa} & G^a_{re} & PE^a_{pa} & PE^a_{re} & TE^a_{pa} & TE^a_{re} \\ \hline G^a_{pa} & V(G^a_{pa}) & COV(G^a_{pa},G^a_{re}) & 0 & 0 & 0 & 0 \\ PE^a_{pa} & 0 & 0 & V(PE^a_{pa}) & COV(PE^a_{pa},PE^a_{re}) & 0 & 0 \\ TE^a_{pa} & 0 & 0 & 0 & 0 & V(TE^a_{pa}) & 0 \end{array}$$

Assuming G and PE effects on part records remain constant throughout the life of a cow (i.e. part records in different lactations are considered to be the same trait), then the variance (covariance) structure between a complete record from lactation *a* and a part record from lactation *b* is as follows:

$$\begin{array}{c|cccccc|} & G^a_{pa} & G^a_{re} & PE^a_{pa} & PE^a_{re} & TE^a_{pa} & TE^a_{re} \\ \hline G^b_{pa} & V(G^a_{pa}) & COV(G^a_{pa},G^a_{re}) & 0 & 0 & 0 & 0 \\ PE^b_{pa} & 0 & 0 & V(PE^a_{pa}) & COV(PE^a_{pa},PE^a_{re}) & 0 & 0 \\ TE^b_{pa} & 0 & 0 & 0 & 0 & 0 & 0 \end{array}$$

Then the phenotypic correlation between a complete record from lactation *a* and a part record from lactation *b* is as follows:

$$r_{(P^a_{comp},\,P^b_{pa})} = r_{(P^a_{comp},\,P^a_{pa})} - (1 - R_{pa})\sqrt{V(P_{pa}) \;/\; V(P_{comp})}$$

where r is the correlation and R_{pa} is the repeatability of partial records, at 60 days in milk.

It was assumed that $R_{comp} = R_{pa} = 0.60$ and heritability (**h**^{2}) was assumed to be 0.30 for both traits. If the correlation between P_{comp} and P_{pa} of the same lactation is 0.78 and the ratio $V(P_{pa}) / V(P_{comp})$ is 0.73 (1), then the phenotypic correlation between part and complete records from different lactations is equal to 0.44. Standard selection index procedures for multiple traits were then employed to calculate accuracies of selection. To test the sensitivity of these assumptions, h^2 was reduced to 0.2, and the correlation between G_{comp} and G_{pa} was also reduced to 0.55.

Flow of Information for Genetic Evaluation of Yield Traits

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ABSTRACT

Calculation of genetic evaluations requires lactation information from monthly milk recording in DHI herds and pedigree information from breed associations. Regional dairy records processing centers accumulate monthly yield data into lactation records, prepare management reports, and transmit completed (monthly) and in-progress (at least semiannually) lactation records to USDA. Pedigree information also accompanies yield records. At USDA, disk data files are updated as new data are received. Yield or pedigree records that are inconsistent with existing data or have values outside acceptable ranges are returned to the source. Lactation records are standardized for age and month of calving. Pedigree and yield information are transferred to a reduced instruction set computer for calculation of genetic evaluations. Iteration is conducted separately for each trait (milk, fat, and protein). After iteration, reliabilities are calculated. Genetic information is combined across yield traits and transferred back to the computer on which the data are maintained. Supplemental information on lactation status and percentile rank is added, and distribution formats are prepared. Reports are sent to owners for bulls; computer tapes are sent to processing centers, breed associations, and other cooperators for both cows and bulls. Evaluations based on 36.6 million lactations from 7 breeds can be calculated in 1 wk. All record processing from receipt of last data to release of evaluations can be accomplished in 6 wk.

Abbreviation key: DRPC = dairy records processing center, **ID** = identification, **MFP$** = index based on the economic values of PTA for milk, fat, and protein yields, **NCDHIP** = National Cooperative Dairy Herd Improvement Program, **RISC** = reduced instruction set computer.

INTRODUCTION

The rate of genetic progress can be improved by increased evaluation accuracy and shorter generation interval. Tradeoffs between these goals may occur because selection at younger ages usually is based on less information. More frequent evaluation reports, faster turnaround times, and the use of more current data can help breeders both to reduce the time between generations and to increase the accuracy of selection.

Genetic evaluations of dairy cattle have contributed to genetic improvement of yield traits. For Holstein cows, the annual increase in milk yield has reached 1.9% of mean milk yield (USDA, unpublished results). Genetic improvement makes a major contribution to this increase. This impressive rate of genetic improvement reflects the availability of high quality data through the National Cooperative Dairy Herd Improvement Program (**NCDHIP**), the application of sophisticated computational procedures, the acceptance of results by the dairy industry, and the investment in sire development programs by AI organizations. To maintain or increase this improvement rate, new technology must continually be adopted. The constant improvement in computer equipment and in computational methods allows the use of more appropriate models and reduces the time needed to compute solutions.

Accuracy of genetic evaluations has been closely tied to the computing power available. The 1989 US implementation of an animal model (8, 10) relied on access to the supercomputer at Cornell University (Ithaca, NY). However, because the Cornell National Supercomputer Facility is intended for research and development rather than production processing, a permanent computing site was needed. Reduced instruction set computers (**RISC**) can be configured as low-cost servers that provide raw computing power that rivals that of supercomputers. The Holstein Association (Brattleboro, VT) routinely computes its animal model evaluations for type on a Sun (Sun Microsystems, Inc., Mountain View, CA) RISC server (2).

Acquisition of an IBM (Armonk, NY) RISC System 6000 POWERserver computer by USDA supplemented the computing resources already available through the Animal Improvement Programs Laboratory's IBM 9370, Model 90, and allowed the January 1993 genetic evaluations for the US dairy cattle population to be computed locally instead of on the Cornell supercomputer. Use of an in-house server avoids delays caused by 1) moving tapes between computing centers, 2) competition among users on a shared machine, and 3) system changes beyond user control. Although new computer programs were developed for the new computer environment, the statistical model and the iteration method (8, 10, 11, 12) were not changed. Approximately 1 wk was required for the calculation of national genetic evaluations, the same as was required with the supercomputer. This report presents the current flow of information through the evaluation system and discusses potential improvements.

DATA ACQUISITION

Data flow among NCDHIP cooperators is in Figure 1, and the quantity of data exchanged for January 1993 evaluations is shown in Table 1. The yield information used to calculate USDA evaluations originates in NCDHIP herds across the US. For most official DHI plans, a supervisor observes and records milk weights monthly and takes samples of each cow's milk. The owner records calvings, breedings, estrus, and management information. The supervisor may transfer this information from the original records to data entry forms. Recently, much of the data entry has shifted to the farm, where the supervisor or owner directly updates the data base at the dairy records processing center (**DRPC**). The data also may be entered at the testing laboratory or at the DRPC. Some advanced on-farm systems include electronic identification (**ID**) and milk weight recording. The cost of milk recording is reduced in some testing plans by observing only one milking on sample day. Experimentation with other innovative testing plans is underway.

Milk samples are sent to testing laboratories for determination of component (fat and protein in all states; SNF in some states) content and, in most cases, SCC. Testing information typically is transferred electronically to the DRPC, where data bases are updated, monthly reports are generated, and lactation records are computed. The DRPC sends computer tapes with lactation information to USDA for use in genetic evaluations. Completed lactation records are sent monthly, and records in progress are sent at least semiannually.

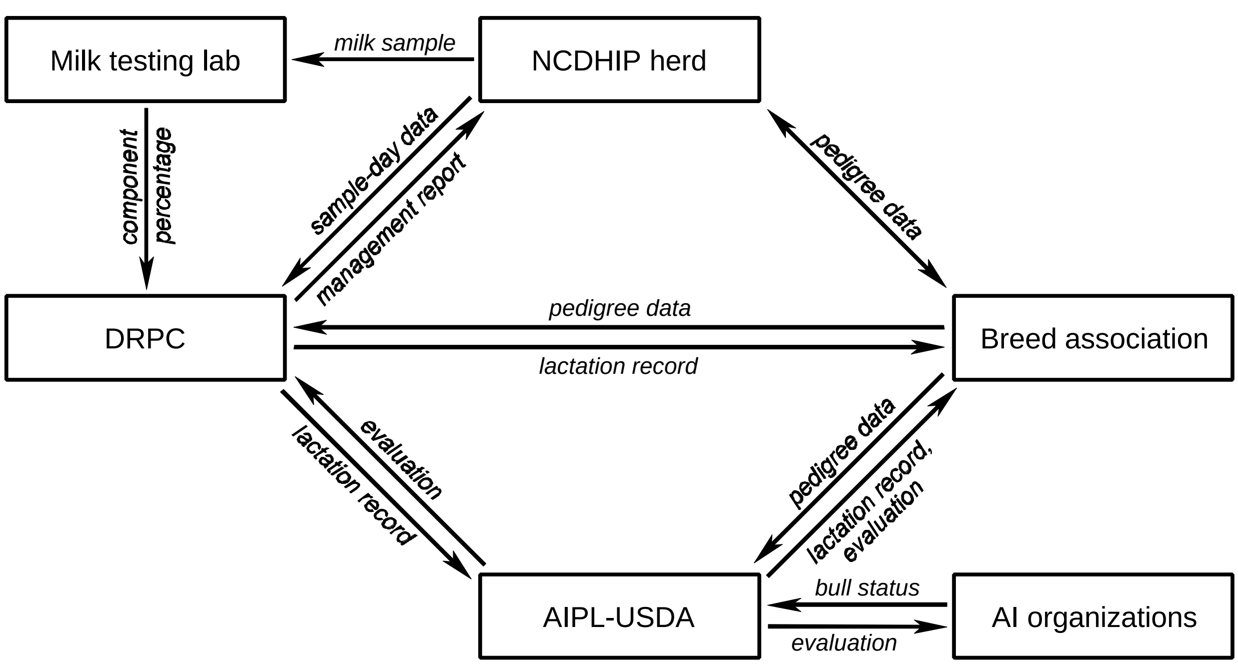

Figure 1. Flow of data among NCDHIP cooperators (AIPL = Animal Improvement Programs Laboratory) for genetic evaluation of yield traits.

TABLE 1. Volume of data transferred on computer media between USDA's Animal Improvement Programs Laboratory (AIPL) and other NCDHIP cooperators for January 1993 genetic evaluations.

Type of record	Sender	Recipient	Number of records	Bytes/ record	Number of Mbytes
Completed lactation	DRPC[1]	AIPL	2,135,757	260	529.6
In-progress lactation	DRPC[1]	AIPL	2,123,890	260	526.6
Pedigree	Breed associations[2]	AIPL	1,425,660	100	136.0
Bull AI status	NAAB[3]	AIPL	4353	100	.4
Bull evaluation	AIPL	DRPC[1]	1,045,872	400	399.0
		Breed associations[4]	581,040	400	221.6
		AI organizations[5]	1,626,912	400	620.6
		Other NCDHIP cooperators[6]	2,788,992	400	1063.9
Top 10% cow evaluation	AIPL	AI organizations[7]	2,324,868	400	886.9
		Other NCDHIP cooperators[8]	1,162,434	400	443.4
Bull daughter evaluation	AIPL	Bull owners[9]	1,163,924	400	444.0
Cow evaluation	AIPL	DRPC[1]	11,357,053	400	4332.4
		Breed associations[4]	8,302,860	400	3167.3
		Other NCDHIP cooperators[10]	1,308,144	400	499.0
Registered completed lactation	AIPL	Breed associations[4]	515,410	260	127.8
Error notification	AIPL	DRPC[1]	407,000	423	164.2
		Breed associations[4]	23,369	263	5.9

[1] 9 dairy records processing centers.
[2] 7 breed associations.
[3] National Association of Animal Breeders.
[4] 5 breed association processing centers.
[5] 14 AI organizations.
[6] 24 US and international university and research organizations.
[7] 12 AI organizations.
[8] 6 US and international university and research organizations.
[9] 11 bull owners.

[10] 2 US universities.

USDA DATA BASE

In addition to the lactation records provided by the DRPC, pedigree information is provided at least semiannually by breed associations. New data are checked on the IBM 9370 as they are received for consistency with existing data and reasonableness of values. Pedigree information from the DRPC is checked against breed association information, and birth dates are checked against calving dates of the dam. Multiple ID for the same animal are detected by checking for other pedigrees with the same sire, dam, and birth date that are not coded twins or from embryo transfer. For animals with multiple ID numbers, these numbers are changed in both the animal's and its progeny's records to a single value (usually the registration number). Ranges of acceptable values are imposed on yield data (14). Calving dates cannot be closer than 9 mo. In some cases, the sire, dam, or birth date of the incoming record will be changed to match existing data. If there is more than one difference between new and existing data, the new record is rejected. Calving date errors and yields outside limits also cause record rejection. Records are returned to the DRPC if any data are changed or unacceptable.

Pedigree information, calving dates, and herd designation are stored in keyed-access disk files. Keyed access allows retrieval of specific cow or bull information. Birth date of a new animal is checked against dam calving date and parent birth dates to ensure that progeny have birth dates more recent than their parents. Records also are checked to ascertain validity of the reported calving date, days in milk, reason for lactation termination, milk and component yields and component percentages, herd assignment, and type of testing plan. For cows that change herds during a lactation, the lactation is assigned to a single herd. If the cow is in the first herd for 90 d or longer, her partial record from that herd is used. If she changes herds before 90 d in milk, the record from the later herd is used if she was in that herd more than twice as long as in the first herd.

Lactation records are standardized to 305 d (6, 9), two times a day milking (6), and mature equivalence (adjustment for calving age and month) (4, 6) and stored on tape. Disk space is used only to store the information from each lactation that is required for editing. During update of the yield file, lactation records are added or deleted, in-progress records are replaced with records that have more days in milk, and some cow ID may be changed.

COMPUTATION OF GENETIC EVALUATIONS

Pedigree and lactation data are transferred from the IBM 9370 to the RISC server, which has 512 Mbytes of memory and over 10 Gbytes of disk storage. The ability to store large amounts of data in memory enables fast access to the data. The data transfer rate from the IBM 9370 to the server is 30 kbytes/sec using a gateway computer connected to the server through Ethernet and to the IBM 9370 through Token Ring. The IBM 9370 communications software determines the data transfer rate. To offset this relatively slow rate, transfer is optionally limited to new, changed, or deleted records. Record size is minimized by representing most values in 2-byte integers. Data for Holsteins and Red and Whites are processed together as a breed group. The memory requirement for Holstein/Red and White data is reduced by defining groups of herds as superherds (7) and retaining only animals that receive contributions from more than one superherd in memory across superherds.

Data Preparation

Herds first are assigned to superherds. Then lactations are assigned to management groups based on calving date, parity, and registry status. Records are created to determine which animals should be evaluated and which animals receive information from more than one superherd through their own records or their progeny (tie animals). Data for year-region variances used in adjustment for heterogeneous variance (12) are collected as is a file of cows with lactations in more than one herd. Superherd assignments are sorted by cow and combined across herds.

Pedigree data are matched with the previous evaluations and with the tie determination file. This new file of pedigree data is sorted by descending birth year. By processing by descending birth year, all ancestors are collected, and tie status of progeny is propagated to parents. Parents with only one progeny and with neither parent evaluated are removed. Ancestors without pedigree data are retained if they have two or more progeny. The pedigree file then is sorted by superherd and birth year.

Animal ID and other defining data for model effects are recoded to equation numbers for iteration. Tie animals are processed first. Animals local to the superherd have numbers above tie animals. At the start of each superherd, data for local animals are read into each of the vectors following the data for tie animals. Memory allocated for local animals is reused for each superherd. The management group assignments are associated with the lactation records, which are adjusted to standardize genetic variance across time and herds (12). Information for lactations without management group mates is not included. Data for milk, fat, and protein are stored together but are accessed separately by trait in the iteration and reliability programs. Milk yield for only those records with protein data also is evaluated so that an evaluation for protein percentage can be calculated from milk and protein evaluations derived from the same data.

Iteration and Calculation of Reliability

During the first iteration to solve the animal model equations, data are stored in vectors that each contain all the data for each factor for a superherd. This method of storage reduces the time required for subsequent iterations. Iteration is continued until the convergence criterion (sum of squared differences divided by sum of squared solutions) is less that 1×10^{-7}. About 60 rounds of iteration have been required to reach convergence; one round for Holstein/Red and White milk yield required 15 min. Three files are required for animal solutions: one for writing new solutions, one for solutions from the previous iteration, and one for solutions from the iteration preceding the previous iteration. The last file is required because second-order Jacobi iteration is used for animal solutions. For other effects, only two files are used. Evaluations are calculated by successively computing estimates of the management group, herd-sire, permanent environment, animal, and unknown-parent group effects (10). Solutions for tie animals are computed at the end of each round of iteration. The relaxation factor used in second-order Jacobi iteration is increased from 0 by .05 each round to a maximum of .88.

Reliability (5), yield deviations, and predicted producing ability are computed after iteration is completed. Solutions are matched with yield data to obtain unadjusted data for mean yield. The adjustment for the genetic base (10) is subtracted from animal solutions. Management group solutions are computed to reflect the latest animal solutions and the base adjustment. A record for each herd-cow combination is written as is a record for cows with data in more than one herd. A record for each sire represented in the herd and data for cows without a reported first lactation are prepared using the management group solutions. Contributions to reliability from yield records are collected. For each superherd, pedigree data are processed by descending birth year so that progeny can contribute to parents and then by ascending birth year so that parent-average reliability can contribute to progeny reliability. At the end of the data, tie animals are processed, and then reliabilities for local animals in each superherd are recomputed using the new values for the tie animals. Evaluation information is written separately for bulls and cows after the second iteration of reliability calculations. All output files are sorted in animal order.

Combination of Evaluation Data and Output Preparation

Data for cows without a reported first lactation that were born in the preceding 10 yr are combined across traits and herds and used to compute a supplemental evaluation. Data for all cows are combined across traits and herds to produce a file of prior evaluations, a short evaluation file, and a detail file for cows born in the preceding 10 yr or with evaluated progeny born in the preceding 20 yr.

For bulls, data are combined across traits, and daughter information is combined across herds. For daughters with lactations in more than one herd, each daughter's lactations are combined across herds to produce information on a daughter basis that can be appropriately weighted and combined with information for other daughters.

Evaluation data are transferred to the IBM 9370 at a rate of 50 kbytes/sec and written to keyed-access files. For bulls also evaluated in Canada at 7 yr of age or younger, a combined evaluation is calculated (13). Parent averages for progeny-test bulls are computed. Supplementary information on lactation status and percentile rank for an index based on the economic values of PTA for milk, fat, and protein yields (**MFP$**) is added and distribution formats are prepared.

DISTRIBUTION OF GENETIC INFORMATION

Computer tapes (round reels and cartridges) with bull evaluations are sent to over 50 recipients: breed associations, DRPC, AI organizations, and other NCDHIP cooperators (Table 1). In addition to data transferred on computer media, numerous printed reports and microfiche are distributed to the dairy industry, including bull evaluation and daughter lists sent to over 3800 bull owners. Subsets of cow evaluations are sent to many of the same industry groups. The AI organizations receive evaluations for daughters of their bulls and the top 10% of registered cows for MFP$. Distribution of information is wider for bulls in active AI service and cows of high genetic merit. Elite status is assigned to the top 1% of Holstein cows for MFP$ and to larger percentages of other breeds. Microfiche is available with genetic information for bulls of possible interest to breeders and for both registered and grade cows with high MFP$. Lactation and genetic information for daughters included in a bull's evaluation is sent to bull owners. Some data are distributed on diskette and via electronic mail. The same format generally is used for cow evaluations for all recipients of electronic data. For bulls, a shortened version of the standard format is used for electronic mail transfer. Pedigree and evaluation information are available online at USDA primarily for problem resolution. Breed associations and DRPC are allowed access.

FREQUENCY OF EVALUATION

Several industry groups are interested in immediate access to genetic evaluations. Dairy producers want updated evaluations of their cows as an extension of milk recording. Cows add information to their lactation records each month that could be included in evaluations. The monthly mailing from the DRPC to herd owners provides a natural channel for distributing information. Genetic evaluations of cows currently milking in the herd could be reported to the herd owner following each evaluation or made available for online query. Producers also want to have access to current genetic information for bulls when purchasing semen.

Sire analysts in AI organizations want evaluations for their young bulls as soon as possible, even if the bull has only one daughter. This preliminary information assists in determining which young bulls should have semen collected in preparation for marketing. More rapid turnaround of data from the national evaluation system could save AI organizations from the considerable effort currently spent in collecting data from individual DRPC to predict a bull's eventual evaluation. However, these organizations prefer that evaluation information for young bulls not have general industry distribution until the decision is made to release the bull's semen so as to limit queries on bulls that are not being marketed. The AI organizations also want information on their competition to assist in pricing and advertising. Current genetic information on top cows is important for sire analysts to plan matings.

Breed association personnel are concerned with minimizing the expense of data processing while still providing owners of registered cattle with current evaluation information. If dairy producers receive updated evaluations frequently, breed associations will be forced to update their files at the same frequency. National evaluations were calculated 3 times per year until 1978, when the current semiannual frequency was adopted (1). One evaluation was dropped to reduce cost to USDA and to allow time for data excluded from one evaluation to be corrected and resubmitted in time for the following evaluation. With computations transferred to a local server and continuous editing of data, additional evaluations during the year are practical.

Misztal et al. (3) found type evaluations to be stable for weekly evaluation of bulls with many daughters.

Evaluations changed when substantial new data were added. For yield evaluations, changes should be less pronounced because records in progress are used. Each month, a small amount of new information is added for many animals.

The benefits of more frequent evaluations include more timely decisions on which bulls to promote to active AI service, less time between when data is collected and when evaluations are available, and quicker results from corrections. The disadvantages to USDA are the extra work of doing the additional computations and the distribution costs. For DRPC, the disadvantages are providing records in progress for evaluations and updating data files with new results. From the perspective of AI organizations, considerable marketing cost is associated with preparing advertising materials, which become obsolete following each evaluation. To achieve the data transfer rates required for continuous evaluation, submission and retrieval of data through a network is necessary.

For more frequent evaluations to be cost effective, some information may need to be suppressed to minimize computation and distribution expenses and to reduce confusion associated with continually changing evaluations. Frequent, large fluctuations in evaluations could undermine confidence in the evaluation system. For cows, distribution of additional evaluations could be limited to those receiving an evaluation for the first time and those with evaluations that changed more than some threshold. These restrictions would reduce the data processing burden while still providing information of interest to many industry groups. For bulls, distribution of additional evaluations could be limited to bulls being progeny tested. These restrictions are useful only if they save processing and marketing costs and provide information adequate to meet industry needs. Online availability of updated data for bulls and cows likely is the long term solution.

Times required to acquire data, to compute genetic evaluations, and to distribute genetic information to the industry are in Figure 2. Time needed for tape transfer from DRPC to USDA is based on the use of first-class US postal service. Actual turnaround time allows for weekends, holidays, and a margin for error and currently is 8 wk from receipt of last data to release of evaluations. Several weeks are required to prepare the data because all active cows contribute records in progress just before the start of evaluation processing, and the yield file on tape must be updated. Evaluations for January 1993 based on 36.6 million lactations from 7 breeds (31.2 million Holstein/Red and White records) were computed on the server in less than 1 wk. Preparing distribution files requires almost 2 wk, with most of the time needed to sort and to copy the large files of cow evaluations. The current evaluation system would not be able to calculate evaluations more frequently than every 2 mo.

Additional evaluations with limited distribution could be released in April and October within the constraints of the current system. These additional evaluations could benefit the industry while being within present computer capabilities. Further automation and simplification of distribution procedures may be necessary so that these tasks can be accomplished within the allotted time without increased staffing. With the availability of additional evaluations, AI organizations probably would no longer require DRPC data for predicting evaluations of young bulls. Funds used for DRPC data could be redirected to financing the cost of providing additional records in progress. Thus, AI organizations and DRPC might be able to provide more information to customers at little extra cost.

FUTURE OPTIONS

To make genetic information more easily available and up to date, some calculations could be made on the farm. Milk recording systems might provide local updates of cow evaluations by combining new data with existing genetic estimates. Alternatively, new data could be automatically transmitted to and from a central site where national evaluations are computed essentially continuously with dedicated equipment. The data base would be accessible worldwide so that the latest evaluations could be retrieved whenever needed. Advertising information would have to be dated, and potential buyers could request more up-to-date information at the time of purchase.

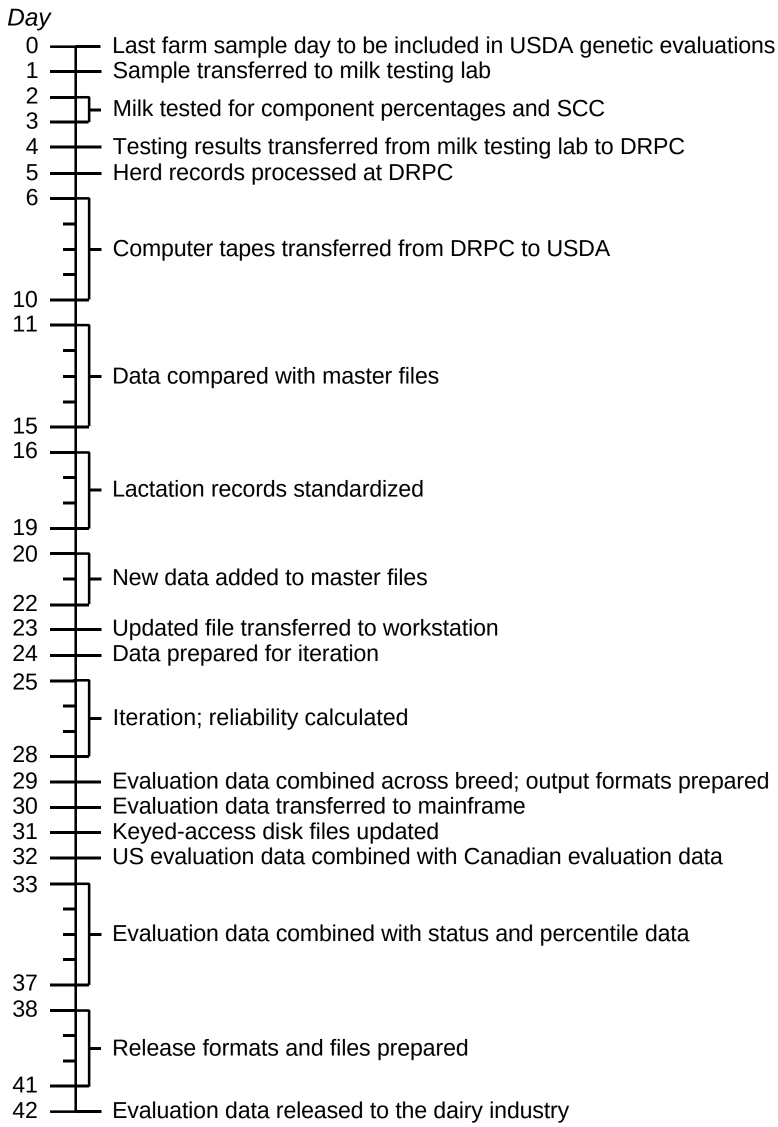

Figure 2. Times required to acquire data, compute national genetic evaluations, and distribute genetic information to the dairy industry.

This future vision exceeds the service for which most dairy producers presently are willing to pay. The necessary communications capability is developing rapidly, and high speed, reliable computer connections may be available to almost everyone soon. Standardization across DRPC and farm computers would be necessary to generate local evaluations and send new data so that they could be easily incorporated into the national data base.

At USDA, all computations could be done on the server. This would allow greater automation and elimination of transfer time. Built-in checking would be required for largely unattended operation. Additional computer storage and connectivity improvements also would be necessary. With improved connectivity, cooperators could send data electronically and request individual evaluations, thereby reducing the time needed for data preparation and distribution. With such a system, evaluations could be ready for release to the industry 2 wk after the last data reached the computer. Hierarchical access could be provided; USDA would provide access to DRPC and breed associations, and then these organizations could serve producers.

CONCLUSIONS

Genetic evaluations for yield could be produced as often as six times per year with current programs and perhaps more frequently in the future. The purpose of more frequent evaluations is to enhance the rate of genetic improvement by enabling selection decisions to be made sooner. Dairy producers could have cow evaluations that include more recent yield information, and AI organizations could have more complete and accurate information on young bulls. The challenges are to distribute the information so that these goals are reached in a manner acceptable to the dairy industry.

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Technical Considerations in Implementation of Continuous Genetic Evaluation

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ABSTRACT

Currently, computation of genetic evaluations at the Holstein Association of America or USDA takes about 6 wk, mostly for various editing and output preparation steps on a mainframe computer. Evaluations are semiannual. Although more frequent evaluation is technically possible (up to eight per year), considerable labor resources would be needed. A computing system is proposed, where operations would be largely automatic and evaluations could be updated in <2 wk. The system would consist of UNIX workstations running database management systems and connected via dial-up lines. New records and queries would be submitted electronically. Queries could request only evaluations that have changed significantly recently. The hardware cost of the proposed system is $110,000, but this cost could be halved if USDA and the Holstein Association continue to downsize from mainframe computers to UNIX workstations. Programming costs can be minimized if frequency of evaluation is considered while downsizing. Annual operational cost of electronic data transfer between USDA, the Holstein Association, and their cooperators is estimated at $40,000. After downsizing, USDA and the Holstein Association should be able to provide frequent evaluations without large investments.

Abbreviation key: CE = continuous genetic evaluation, **DBMS** = database management system, **DRPC** = dairy records processing center, **HA** = Holstein Association of America, **NCDHIP** = National Cooperative Dairy Herd Improvement Program, **QS** = query system.

INTRODUCTION

Technically, continuous genetic evaluation (**CE**) requires consideration of three issues. First, a model should be free of time constraints. For example, if herd-year-seasons were defined as April through September and October through March, the evaluations would be less accurate in periods beginning in April and October because of a smaller number of contemporaries. Second, a computing procedure should update the animal model solutions, given new records, in relatively short time. With current fast computers and expensive software development, using animal model programs prepared for the present semiannual evaluations might be more acceptable than developing specialized CE programs. These two issues have been discussed in detail (9). Third, a computing environment is needed to transfer data between record providers, evaluation, and distribution centers, to select records qualifying for the animal model evaluations, to launch the animal model programs, and to process and to provide electronic access to the updated evaluations. The goal of this paper is to present a hypothetical computer environment for CE and to estimate the cost of its implementation and operation. Only plans for U.S.Holsteins are presented; however, the solutions developed for U.S. Holsteins can be adapted for other breeds and/or countries, likely at much lower costs.

CURRENT EVALUATIONS AND CE

Current Evaluations

Currently, computation time for genetic evaluations of Holsteins for yield and type traits takes about 6 wk (T. J. Lawlor and G. R. Wiggans, personal communications, 1993). A breakdown of that time for the Holstein Association of America (**HA**) and USDA is in Table 1. Only about 1 wk is spent in processing the animal model solutions. Because of greater speed and memory requirements, this step is performed on a UNIX workstation. The rest is spent in various data manipulation steps, mostly on a mainframe. Because completing evaluations on time is extremely important, the total processing time includes a reserve.

TABLE 1. Timeframe for current computation of semiannual evaluations at HA and at USDA.

Operation	HA	USDA
	(wk)	
Loading new records into database	. . .[1]	1.0
Extracting records qualifying for the main evaluation	1.0	.5
Validating and preadjusting	.5	.5
Animal model evaluation	1.0	1.0
Formatting output	2.0	1.5
Workstation-to-mainframe transfers	.5	.5
Reserve	1.0	1.0
All operations	6.0	6.0

[1]New records loaded throughout the year.

Data manipulation steps are slow for many reasons. A large volume of new data accumulates during each 6 mo between evaluations. Computer tapes, which are used extensively for data input, output, and intermediate operations, have to be mounted manually, which prevents 24-hr operation. Steps that could be performed much faster by workstations are limited by a slow transfer rate between the workstation and the mainframe. Finally, data manipulation steps are done by many custom programs. Under changing requirements, these programs are difficult to modify, which causes dependability problems and requires verification of results after each step before the next one is launched. Consequently, operations cannot be streamlined. Although more frequent evaluation presently is possible (up to eight per year), much effort would be required because of the current computing environment.

CE

For CE, new data would be received and evaluations sent electronically rather than on tape. Evaluation programs would run continuously (9). If one evaluation cycle took 2 wk, evaluations could be updated as often as 26 times per year. Such frequent evaluation requires a computer environment different from the current one. For realistic CE, most operations would have to be automatic with human assistance limited to maintenance, monitoring, and modifications. To ensure industry acceptance, implementation costs must be small. Surprisingly, both objectives can be accomplished because of a downsizing trend underway at HA and USDA. Downsizing (1, 5) is a move from mainframes and proprietary technology to open standards and smaller computers, which, in this case, are UNIX workstations or servers.

A CE output would primarily be evaluations for new animals and evaluations that changed significantly rather than all evaluations. Additionally, each changed evaluation could be supplemented by a code describing the principal reason of change such as new record, more contemporaries, change in sire evaluation etc. Concern has been expressed that more frequent evaluation would cause a flood of information if updated evaluations on millions of animals are available too often. Evaluations for very few animals change perceptibly over a short time (9), and the CE system will need mechanisms to identify these animals.

MODERN TECHNOLOGY FOR CE

Several technological developments make CE technically feasible (12). Fast, inexpensive UNIX workstations or servers (terms used interchangeably in this paper) are over a magnitude faster than mainframes in the same price range. Workstations are easier to upgrade and to manage than mainframes, and they also have built-in networking capability (11). Programming tools included in UNIX simplify programming. Helican-scan tape drives provide a basis for extremely low-cost, automated offline storage for a large amount of temporary, backup, or archival data. For example, an automated tape library consisting of 60 robot-loaded cartridges and two 8-mm drives (e.g., from Exabyte or Comtec) costs twice as much as an industry-standard 3480 cartridge drive but offers capacity 1250 times larger. The library needs no operator to change tapes.

In electronic data transfer, inexpensive 14.4 kbaud modems transmit at speeds up to 1.5 kbytes/s over telephone lines. By using standard compression software, the volume of dairy data can be reduced 2 to 4 times. Then, the effective transfer rate can exceed 4 kbytes/s, which at current long-distance prices is below $1/Mbyte. Emerging modem standards of up to 28.8 kbaud will result in even lower costs. Additional savings could result from the use of digital transmissions (integrated service digital network) over dial-up lines. This standard, which increases transmission rate to 57.6 kbaud, is already available in many areas.

An important component of CE is a database and a database management system (**DBMS**) (7). A DBMS organizes many files, possibly on many disks, into a single database. Because of reduction in data redundancy and an automatic management of disk space, data organized into a database take less space while having increased integrity. Because a DBMS handles many details in processing the database, application programs using a DBMS are less complicated and more dependable than programs operating with separate files. Modern databases contain tools for fast creation of interactive query systems (**QS**).

Workstations may require different problem-solving approaches than used for mainframes. For instance, workstations use leading-edge technology; therefore, their software and hardware may not be as reliable as those for mainframes. Occasional problems must either be tolerated or minimized by using redundant hardware and extensive system testing after any software or hardware upgrade. Helical and other tapes developed for workstations are unsuitable for tape-to-tape processing, which is common on mainframes. Therefore, files on tapes cannot easily be processed until they are brought to a disk. Solutions to this problem are obtaining more disk space, which is much less expensive for workstations, and using UNIX compression facilities. Efficient sort programs are essential for fast data processing on mainframes, but sort programs available under UNIX are not nearly as efficient as sort programs on mainframes. On workstations, sorting may be minimized by using memory-intensive algorithms or by processing with a database, which has its own data manipulation capabilities.

DESIGN OF THE CE SYSTEM

For simplicity, data flow for the dairy industry is depicted as in Figure 1. Data providers supply data to the evaluation centers, which in turn distribute the evaluations to evaluation users. Data providers include dairy records processing centers (**DRPC**) and breed associations. The evaluation centers are HA and USDA. Evaluation users include dairy DRPC, AI organizations, and breed associations. For details on the data flow in the dairy industry, see Figure 1 in Wiggans and VanRaden (13).

A CE system, which should be implemented by each evaluation center, could consist of a DBMS to store all information, a QS to provide user access to that information, and a communication system to access QS remotely. Ideally, CE would be implemented via a distributed database maintained on evaluation center computers (USDA and HA). For efficient operations, the computers would be networked permanently, and all would run the same DBMS. Such an approach may be unrealistic because of high costs; therefore, the proposed CE environment assumes the existence of separate DBMS for each evaluation center and on-demand rather than permanent communication. Only an outline of the CE system is described below. In the actual implementation, details could be modeled by structured analysis (14).

Figure 1. Simplified data flow for genetic evaluations.

DBMS

To achieve high performance, the DBMS (separate for each evaluation center) would keep data in three overlapping databases. The main database would contain comprehensive information for all animals. It would be designed to provide fast access to records for individual animals; however, because of its size, scanning all records would be slow. The animal model database would contain only the part of the main database that is required for animal model evaluation. It could include extra fields used by the animal model program such as management group number or consecutive animal number. This database would ten times smaller than the main database, and its access would be customized to generate input quickly for the animal model programs. The third database would contain time-stamped results of several recent evaluations. To decrease the volume of information, only results for live animals would be stored, and new evaluations that do not change over a certain threshold would not be entered. More information would be stored for bulls.

QS

Transfer of new records and access to evaluations and other information in the database would be provided by the QS, a subsystem of the DBMS. The access would be by file transfer, mail, or interactive. The file-transfer mode would be used for transfer of large data sets to and from the query computer; this service likely would be used between major cooperators (USDA, breed associations, DRPC, and AI organizations). Requests for file transfer would be submitted by mail. Queries that result in extensive output or that require lengthy processing also would be submitted by mail; the results would be returned later by file transfer or by mail. In the interactive mode, selection of services would be through a user friendly interface program and would require little training for common queries. For all transfer modes, each requester would be limited to information only for animals to which access had been authorized. For example, queries could request information for any cow or bull or the list of top bulls (cows) according to a preselected or specified index with the animals restricted within the allowed access for the requester. The output of any query can be time-filtered by requesting only such data that have changed recently.

User interface to the QS is the most visible and, therefore, most important part of CE. Depending on needs, type of terminal emulation, and amount of programming investment, the QS could support line-mode, full-screen, or graphical interface. In the last case, graphs could present comprehensive information on selected animals, which would simplify selection decisions.

Communication System

Electronic communication would utilize three techniques. The first is a dial-up terminal emulation provided by programs such as PROCOMM or KERMIT (3). It would primarily be useful for online queries. Emulation programs could be used to transfer files with relatively good performance; however, they are not suitable for unattended and consequently large data transfers. The second communication technique would use the industry-standard TCP/IP protocol (2) over Internet, a public data network with connections worldwide (6). This protocol offers a comprehensive set of services that include file transfer and electronic mail, and connections to anyone on the network are easily accomplished. Setup of TCP/IP is initially complicated, and, for good performance, it requires fast and permanent connection to an Internet gateway. In major US cities, a medium-speed connection call to an Internet gateway already is available commercially at a cost comparable to a daily 1-h long-distance call. Such a connection uses a local dial-up line, and its cost is independent of the data traffic. The last communication technique would be provided by UUCP protocols, which support unattended file transfer, mail, and remote command execution (10). The UUCP programs, which connect to other UUCP partners at preset times of the day, operate primarily over dial-up lines and are available at low or no cost on many computing platforms. They are easy to set up and require no network connection. Internet is the preferred medium for transferring data for sites where data volume is high and an Internet connection is available because of Internet's extensive capabilities and greater speed potential. For other sites, UUCP would be more economical. In the proposed CE environment, all sites are assumed initially to use UUCP.

HYPOTHETICAL CE ENVIRONMENT

Data Providers

Large providers with a compatible DBMS and computer system. An automatically scheduled program extracts new records from the database periodically (e.g., weekly) and schedules them for transmission to the evaluation center's computer. Any mail received on incorrect records is forwarded to an appropriate contact.

Other large providers. Periodically (daily, weekly, or as often as convenient), the provider schedules new records for transmission via UUCP to the evaluation center's computer and reads any mail. If the mail concerns incorrect records, the incorrect records (already returned via UUCP) are corrected and, after correction, scheduled for transfer.

Small providers. Periodically (daily, weekly, or as often as convenient), the provider connects to its account on the evaluation center's computer, uploads new records, and reads any mail.

Evaluation Center

The detailed data flow for a single evaluation center (HA or USDA) is shown in Figure 2. When new records arrive, they are validated, and the correct ones are entered into the main database. Simultaneously, records useful for the animal model evaluation are entered into the animal model database. After all records are entered, a status report is sent to the provider's administrator mailbox and to the data provider, and incorrect records are returned to the provider via file transfer.

Animal model evaluations are processed continuously, possibly at lower priority during peak usage hours. First, qualifying records are extracted from the animal model database. Then, animal model solutions are computed by the animal model programs. Finally, solutions that changed over a threshold are entered into the evaluation database. Once evaluation processing finishes, it starts again.

After an evaluation cycle is complete, selected evaluation users are sent a customized evaluation summary by electronic mail. Such a summary can include a list of top animals with evaluations that changed significantly and to which the user has authorized access.

After receiving the query request, the QS verifies the access authorization of the query originator. It processes the query, returns the output interactively or by file transfer as requested, and stores the accounting information.

IMPLEMENTATION AND COSTS

Current Status

Currently, both HA and USDA have workstations. A commercial DBMS has been installed by HA, and USDA also plans to do so. Type records already are transmitted electronically to HA, and HA has extensive dial-up capability. Both USDA and HA have mail and file transfer capabilities through dial-up lines; USDA has a dial-up TCP/IP connection, and HA has UUCP. Most dairy industry organizations have personal computers with modems and dial-up terminal emulation programs and that are capable of running UUCP programs.

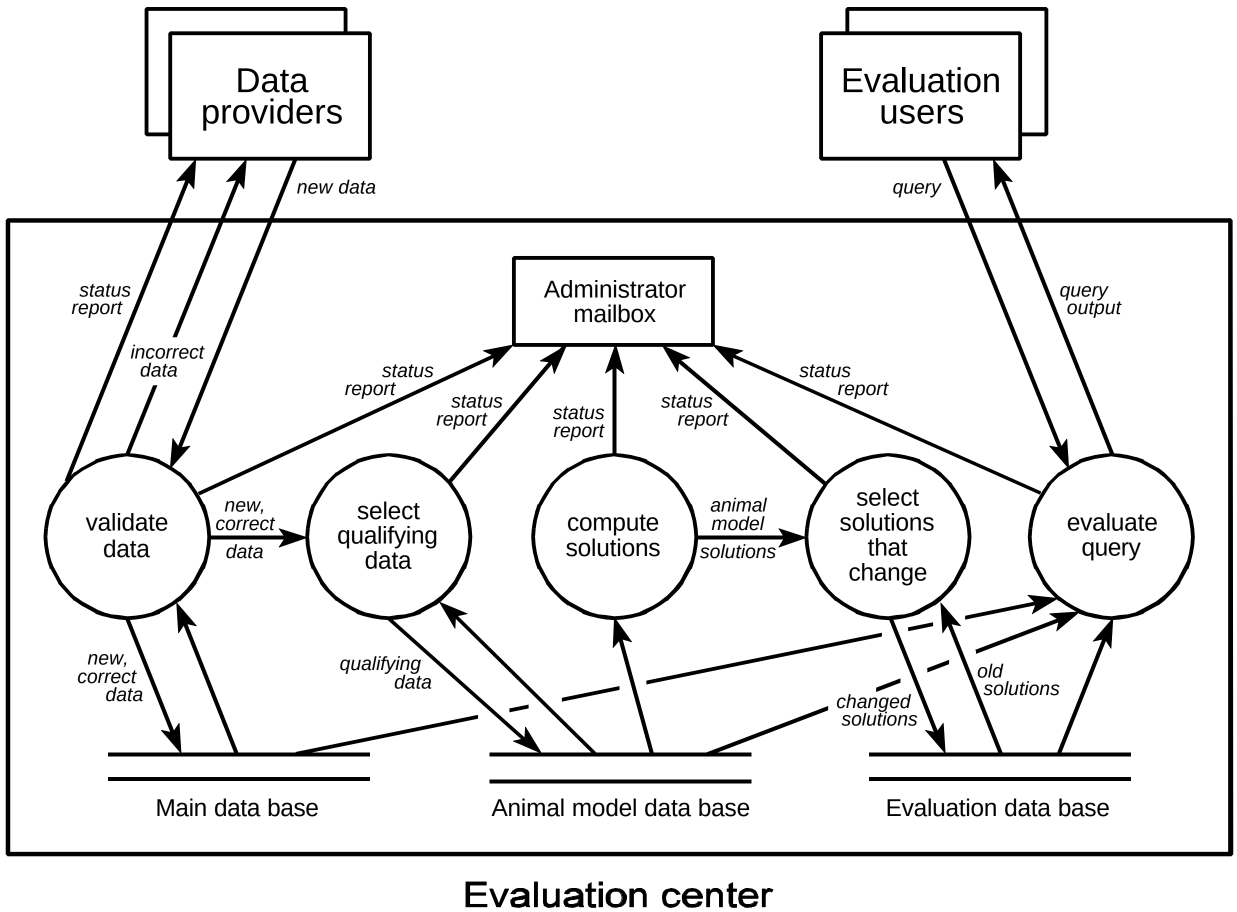

Figure 2. Detailed data flow for an evaluation center.

Implementation Steps

Before setting up a CE environment, the dairy industry would need to agree on procedures and formats for data transfer, rules on access authorization for data and evaluations, and financial charges for algorithm and cost redistribution. Then, computer software and hardware would need to be installed at the evaluation center (HA and USDA): DBMS (USDA only), automated tape libraries with appropriate software, additional telephone lines with high-speed modems, additional disk space for handling query and animal model databases, and additional query workstations. A workstation or personal computer with modem and UUCP software (or Internet connection) also would be needed by DRPC, other large data providers, and evaluation users.

Estimated implementation costs are in Table 2. For HA and USDA, the costs are about $110,000. However, after downsizing is complete, costs may drop to around $50,000. The cost of UUCP communication can range between $250 and $6000 per organization, depending on whether the UUCP software is installed on an existing computer with modem or on a new workstation specially purchased for this purpose. Software development includes setting up the databases, programming the data manipulation steps, and programming the QS. The cost of installing UUCP service is likely to be small. If downsizing is assumed, the database must be programmed regardless of CE implementation except for the QS. To decrease the QS development costs, its design can be incremental and driven by demand. Operating costs include the costs of file transfers, extra personnel to supervise operations, and QS maintenance. Both labor and QS costs are unknown but may be partially offset by current costs.

TABLE 2. Estimated investment costs for CE implementation.

Organization	Hardware/software needed	Cost	Remarks
		$	
DRPC	Computer with UUCP access	250 to 6000	UUCP software for personal computer or a Unix workstation with 14.4 k modem
USDA	DBMS	40,000	May be purchased regardless of CE status
	Automated tape library	7000	For 50-Gbyte model; higher capacity model may be purchased regardless of CE status
	Extra disk space	8000	5 Gbytes of storage
	Dial-up connections (10)	6000	
	Query workstation	6000	May not be necessary
HA	Automated tape library	7000	For 50-Gbyte model; higher capacity model may be purchased regardless of CE status
	Extra disk space	16000	10 Gbytes
	Dial-up connections (20)	12,000	Service may be provided regardless of CE status
	Query workstation	10,000	Service may be provided regardless of CE status

Estimated volume of data transferred and costs of electronic data transfers for all breeds annually are in Table 3. Data transfers between breed associations and cooperators other than USDA are assumed to be one-half of USDA transfers. These estimates also include monthly transfer of records in progress, which now are transferred semiannually by most DRPC. The total annual volume of 47 Gbytes, which includes dairy breeds other than Holstein, can be transmitted over dial-up lines for about $40,000. This cost seems acceptable, given the number of different organizational units it serves. In addition, the cost would be partially offset by costs now incurred in exchanging information on tapes.

Under a CE system, the volume of data transfers may be reduced. Current data contain a high degree of redundancy to facilitate data validation and to minimize requests for additional information outside the semiannual schedule. In particular, evaluations are distributed for all qualifying animals even if their evaluations have not changed significantly. With CE, some of these redundancies may no longer be necessary. In the future, most transfers may use the TCP/IP protocol with a permanent or local dial-up connection where the cost of a connection will be fixed regardless of the volume of data transfers. Consequently, data transfer issues will become less important.

Table 3. Estimated volume and cost of annual electronic data transfers for USDA genetic evaluation of US dairy cattle.

Data transfer	Volume	Cost[1]
	Gbytes	$
Between NCDHIP cooperators and USDA[2]		

Current evaluation system	28.0	23,332
Additional transfers from monthly submission of records in progress	5.2	4,333
Between breed associations and cooperators other than USDA[3]	14.0	11,666
All transfers	47.2	39,332

NCDHIP = National Cooperative Dairy Herd Improvement Program

[1] Assumed transfer rate of 3 kbytes/s (14.4-kbaud modem with compression) and long distance rate of 15¢/min.

[2] Estimated from Wiggans and VanRaden (13).

[3] Estimated as half the current transfers to USDA.

Implementation Schedule

Implementation of a CE environment for genetic evaluation of US dairy cattle could be accomplished gradually. First, USDA would purchase a DBMS. Then, HA and USDA could create the main and animal model databases on workstations. The editing programs then would be rewritten in the database manipulation language. These computing environment changes, which are the most expensive aspects of CE implementation, likely will be undertaken even without CE implementation because of transition to UNIX.

Once the database systems are in place, the industry would have to agree on new data and transmission formats. To facilitate electronic data transmission, USDA and DRPC would install UUCP and extra modems; only additional modems would be required by HA. New records would be transmitted to USDA and HA only electronically. Then, HA and USDA would create the evaluation database and an interactive QS. This phase to help automate evaluations without increasing their frequency likely will cost less than the previous changes to the computing environment.

To test the CE system, frequency of evaluation would be increased until eventually evaluation was continuous. During testing, evaluations would be released semiannually. Finally, evaluations would be released as soon as available.

IMPACT OF EVALUATION FREQUENCY

To assess the impact of various evaluation frequencies on USDA and HA, the time required for editing operations in Table 1 is assumed to be reduced fourfold after processing is moved from the mainframe to a workstation: twofold because of the faster speed of the workstation and twofold because of 24 h/day operation. Further reductions will be realized if smaller data sets are processed. In addition, new records soon will be loaded into the USDA database monthly rather than semiannually (L. G. Waite, personal communication, 1993).

Semiannual Evaluation

If semiannual evaluation is retained, downsizing would be limited to installation and implementation of DBMS, and there would be no changes for NCDHIP or breed associations' cooperators. Loading new records into the database could be reduced 24 times, and extracting, validating, and preadjusting records could be reduced 4 times. Because evaluations would continue to be distributed in the current format (mainly via 3480 tapes), substantial tape handling capability on the mainframe would still be required. The formatting-output time would not decrease, and at least half the time required for transfer of data between the workstation and mainframe would still be needed.

Because workstations, inclusive of software and peripherals, currently are less reliable than mainframes, processing delays would be more likely. Therefore, reserve time would have to be included in processing schedules to ensure that release deadlines were met. Downsizing would reduce evaluation time from 6 wk to 3 to 4 wk, but processing peaks for the evaluation centers and the whole industry will remain.

Periodic Evaluation

If evaluation frequency is increased to quarterly as is being considered by USDA (G. R. Wiggans, personal communication, 1992) or monthly, evaluations would be more timely, and no changes in the evaluation distribution scheme would be needed. However, the number of processing peaks for the industry would increase, and extracting useful information from the increased volume would be the responsibility of evaluation users.

QS and Semiannual or Periodic Evaluation

Under semiannual or periodic evaluation, QS could be only an auxiliary source of information and could not replace tape (and other media) distributions. As a main source, a QS would become saturated at the end of each evaluation because of the need to distribute information to all cooperators simultaneously. Therefore, establishment of QS without CE implementation would be of limited benefit.

CE

With a CE system, processing time would consist of the animal model and evaluation database updates. An evaluation interval of $\leq$2 wk is realistic. The CE system would operate automatically and without firm schedules, which would relieve the industry from deadline pressures. Because evaluations would be updated frequently and asynchronously, new evaluations would be retrieved when needed rather than at the end of every evaluation cycle, queries would be spread throughout the year, and QS could be the main distribution channel. Thus, most costs for alternate evaluation distribution services could be deducted from CE costs. As proposed, the CE system would contain mechanisms to prevent information overflow; e.g., new information would only be available for animals with evaluations that have changed recently. Unlike the current semiannual evaluation system, in which the computing environment must be powerful enough to handle processing peaks while being underutilized the remaining time, CE computations would be spread throughout the year. Therefore, despite larger computing requirements overall, the CE system may not require more computing resources.

CE DEPENDABILITY

A CE system would have to operate online continuously. Therefore, its dependability is extremely important. High dependability can be achieved by separating the QS from the rest of the CE system; as an extreme, QS could even be duplicated. In either case, QS would run on a workstation separate from the other CE components, and it would store a copy of the evaluation database. If the main database or the animal model evaluation components failed, QS could still operate intact. Lack of evaluation updates for a short time should not be important because no firm schedules would exist and evaluations would be much more up-to-date than at present.

As the CE system would be almost completely automated, there is a possibility that a corrupted data transfer could result in erroneous evaluations. Such a possibility is minimized by validating all incoming records. Additionally, if the number of significantly changed evaluations in one cycle of evaluation greatly exceeds the average, the new evaluations mightl not be entered into the databases, pending the CE administrator decision.

IMPORTANCE OF QS

The most significant CE cost would be design, setup, operation, maintenance, and upgrade of a QS. The exact costs are difficult to quantify and depend on the sophistication of the user interface and programmers' experience. Most likely, development of a QS can be done with existing personnel as part of downsizing.

Because the QS is a major cost of the CE system, different QS could be designed for USDA and the breed associations. For USDA, which would have fewer resources and a smaller user base, a QS suitable for accessing large volumes of data via a simple user interface could be developed. For the breed associations, a full-service QS would be needed.

A QS can eventually evolve into an information system for the dairy industry and act as a clearing house for dairy information. Services that are difficult to deliver with limited access to animal information could then be provided. For example, mating services that offer an inbreeding selection criteria require access to an animal's full pedigree to calculate relationships among animals. Rapid increase in inbreeding levels has become a concern for breeders (4). The QS could support research in dairy cattle by making data more easily available.

CONCLUSIONS

This paper presents an implementation strategy for continuous genetic evaluation of dairy cattle. Data providers would transmit new records electronically over dial-up lines using personal computers or UNIX workstations. Evaluation centers would update evaluations on UNIX workstations continuously and make evaluations available electronically. Mechanisms would exist to select only those evaluations that changed recently. Because of downsizing from mainframe to UNIX workstation environments at HA and USDA, most investments for a CE system already have been made. Additional investments could be as small as $50,000. Operationally, electronic transfers of data and evaluations for all breeds would cost about $40,000/yr. Implementation of a CE system is an opportunity for the dairy industry to have the up-to-date genetic and management information with little additional cost.

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Flow of type information and breeders' perspective on the frequency of genetic evaluations.

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ABSTRACT

Type information on Holstein cattle is now being collected and sent back to the industry electronically. With a computer dedicated for genetic evaluations, more frequent evaluations are now feasible. If genetic evaluations are calculated more frequently, changes in PTA values will primarily involve those animals that have been recently classified and their sires. More important than actual change in PTAs may be their relative rank in the population and their inclusion in lists of high ranking animals. In a survey of 1,000 dairy farmers, 70% expressed some interest in more frequent genetic evaluations. The most frequently requested interval was every 3 months. More interest was expressed for more frequent bull PTAs than cow PTAs. With a low percentage (10 to 21%) of the breeders owning computers and modems, educational efforts must be exerted by industry professionals if genetic evaluations are to be provided more frequently than every 3 months. Providing more frequent genetic evaluations for conformational traits for cows will have little effect on breeding decisions. However, the frequency of bull evaluations does influence timeliness of breeding decisions so that bulls of better merit may be selected.

INTRODUCTION

There are several issues which need to be addressed regarding the optimal frequency of genetic evaluations. First, are more frequent evaluations feasible? Misztal's research (3) indicates that it is feasible to calculate genetic evaluations on a monthly basis, both from a technological and economic point of view. Second, are there benefits in calculating genetic evaluations more frequently? Research by Lohuis et al. (2) indicates that increased genetic progress should be obtained from more frequent genetic evaluations. If continuous evaluation is implemented in all paths of selection, 7 to 9% higher rates of annual genetic response is predicted (2). Third, does the industry want more frequent genetic evaluations, or will they be too disruptive? This paper will address the third question, with primary emphasis placed on the genetic evaluations for conformational traits.

CLASSIFICATION PROGRAMS

The Holstein Association evaluates approximately 600,000 cows in 14,000 herds annually, employing 32 full time classifiers and 3 technical supervisors. Technical supervisors monitor the quality of classifiers' work and train new classifiers. Four training sessions are held for classifiers each year to ensure that the classifiers score animals as consistently as possible.

Fifteen linear type traits, five major breakdowns and a final score are obtained for each animal. The classifier evaluates the 15 linear type traits on a continuous linear biological scale of 1 to 50. The description of twelve of these traits has been agreed upon by the World Holstein Friesian Federation (1) and is used in most classification programs around the world. The classifiers also assigns a numerical score (1 to 100) to each of the five major breakdowns. Final score is calculated from the scores assigned to these five breakdowns which are weighted as follows: frame-15%, dairy character-20%, body capacity-10%, feet and legs-15%, and udder-40%. Genetic evaluations are calculated for the fifteen linear traits and final score. Combinations of the linear type traits are presented as composites, i.e., body size, dairy character, feet and legs and udder.

There are two classification programs, the traditional whole herd program and the Sire Evaluation for Type (SET) program. The whole herd program is primarily used by owners of purebred cattle and for animals recorded in the Holstein Association's identification programs. In the whole herd program, a Holstein Association classifier visits each area of the country every seven months. Breeders are encouraged to participate in classification at least once every 14 months. All animals in the herd are evaluated at each classification visit.

All records up to and including the first permanent score (5 years of age) are used in the genetic evaluations. With increasing herd sizes, new options are becoming available which will require only first lactation animals to be evaluated. Scoring of second and later lactation animals will be optional. If the partial herd option is selected, only the scores on first lactation animals are used in the genetic evaluations.

The SET program is designed to help owners of progeny test bulls to obtain a type proof early in the productive life of the bull. The applicant enrolls his bull in the SET program and provides the Holstein Association with a list of the bull's daughters and DHI herd code numbers for those daughters not on the USDA Bull Evaluation and Daughter list. Only the bull's daughters and their herdmates which are less than 43 months of age are eligible for a SET evaluation. A herdmate is defined as a cow sired by any bull other than the SET bull under consideration. Within a particular herd, all eligible daughters of the SET bull are classified along with up to 15 herdmates.

The herdmate selection process begins with a request from the Holstein Association to the dairy records processing centers (DRPCs) to obtain computer files containing the inventories of herds which have daughters of a bull enrolled in the SET program. Herdmates are selected with primary consideration given to lactation number. Secondary consideration is given to registry status. Third consideration is given to stage of lactation. For example, if several herdmate candidates exist that are the same lactation and registry status, herdmates closest to the same stage of lactation as the daughter(s) are selected.

CURRENT DATA FLOW

Herd inventories are obtained from the DRPC after the bull's owner applies for classification in the SET program. A computer file of the herd inventory is sent to the Holstein Association approximately 30 days prior to classification.

Herd inventories are downloaded electronically to Holstein classifiers on a daily basis via terminal emulation programs. Newly freshened or recently acquired animals can be added manually to the inventory by the classifier. Classifiers enter scores directly into hand held computers (DAP Microflex PC 9000). New information is then electronically uploaded to the Holstein database in Brattleboro, VT.

New classification scores are stored on keyed-access disk files. Specific cow and bull information can be accessed electronically by anyone in the dairy industry. Every six months the entire classification database is downloaded to a UNIX workstation. The time involved to download, calculate the genetic evaluations and upload them to the mainframe is approximately 14 days. Half the time is spent on obtaining the genetic evaluations and the other half is spent on data manipulation and quality control.

EXPECTED CHANGES WITH MORE FREQUENT GENETIC EVALUATIONS

One of the fears among users of genetic information is that large fluctuations in PTA of many animals will occur between successive evaluations. Misztal et al. (4) investigated the specific question of magnitude of PTA changes under continuous evaluation in their 1991 paper. They calculated 48 weekly genetic evaluations for data arriving in 1988. During the week of November 18 to 25, 3,468 cows were classified. This information resulted in the following PTAT changes:

Number of animals with absolute PTAT changes larger than a specific amount.

change in PTAT	number of bulls	number of cows
0.10 pts	220	5020
0.50 pts	7	79

Considering that over 2.3 million animals were reevaluated with the addition of the new information, the 5,240 animals with noticeable changes in their PTATs is small. Most of the observed changes occurred among cows and sires of cows classified during that week. For comparison, the standard deviation of the PTATs for the cows born in 1985 is 0.70. The additive genetic standard deviation for final score is 1.9 points.

The PTAs of younger animals have a larger prediction error variance. Therefore, larger changes are expected among younger animals. For example, two popular bulls began 1988 with initial reliabilities of 66% and each added over 300 daughters throughout the year. Proofs on these bulls changed by as much as 1.2 points. Ranking of such bulls in the top 100 TPI list changed by as much as 20 positions weekly or 30 positions monthly.

Time delays in obtaining PTATs may be greater for cows than for bulls. Currently the cutoff date used in each genetic evaluation is approximately 6 weeks prior to the release of new evaluations. Therefore, an evaluation for a cow classified just after the deadline is not updated until 7 months later.

The practical effects of more frequent genetic evaluations for conformation traits on breeding decisions may be limited. The average age of freshening is 27.5 months and the average age at first classification is 33.7 months for cows in the classification program. Therefore, most cows would be in their six month of lactation and would already be bred by the time they are first classified. More frequent evaluations for type would not affect the breeding decisions for most first lactation cows. However, early production information could be included in more frequent genetic evaluations and their availability could influence breeding decisions.

In an unplanned experiment, two weeks of data were inadvertently excluded from the January, 1992 genetic evaluation. Upon discovery, the genetic evaluations were recalculated. Both evaluations were released to the industry. This is the first example of biweekly genetic evaluations known to the authors. The inclusion of data from November 18 to November 31, 1991 added 19,006 records and 9,691 new cows.

Because the primary concern is with the high ranking animals, a brief review of the changes over this two week period is worthwhile. Every 6 months, the top 5000 TPI cows are identified. With the additional information, 82 new cows were identified, and all were either 3 or 4 years old.

Among the top 400 TPI bulls, 35 bulls changed by 0.10 points or more. Seventeen went up and 18 went down and the two largest changes were +0.33 and -0.34. There were 14 and 4 new bulls identified to rank among the top 400 and 100 TPI bulls, respectively.

A bull must have at least 10 daughters to obtain an official type proof. With the addition of two weeks worth of data, 73 additional bulls met this requirement. Their TPI values were high enough for 18 bulls to qualify for the top 400 and 5 to qualify for the top 100. However a minimum reliability requirement of 65% and 70% was necessary for inclusion in the top 400 and top 100 TPI bull lists, respectively. None of the young bulls with first proofs met these requirements.

BREEDERS PERCEPTIONS

In order to obtain the opinions of Holstein breeders, 1,000 dairy farmers were contacted by telephone by Holstein Association representatives. The farmers were randomly selected from two groups. The first group (DHIR herd) consisted of farmers enrolled in the DHIR program of the Holstein Association. Approximately 17% of all Holstein herds in an official DHIA testing program are enrolled in DHIR. The production records of this group must follow additional rules, are subject to verification tests and are eligible for special recognitions. It was believed that this group has an expressed interest in breeding and marketing Holsteins.

In order to obtain the opinions of a broader group of farmers a second group was selected. The second group (WI DHIA herd) consisted of farmers enrolled in an official DHIA program in the state of Wisconsin. It is believed that this group would better reflect the opinions of a typical farmer on official DHIA testing.

Regional differences of the characteristics of dairy farms do exist across the country. For example, Wisconsin farms tend to be smaller than the rest of the country. Although Wisconsin may not be representative of commercial farmers in all parts of the country, it is representative of the amount of interest in registered cattle and participation in the Holstein Association type program. Based on registered Holsteins as a percentage of cows in milk, Wisconsin is representative of the national average.

Approximately, one half of the US herds are enrolled in a DHIA testing program. Of these, two thirds are in an official testing program. Therefore, interpretation of these survey results only apply to those farmers who are directly contributing production information into the national genetic evaluations and routinely receive genetic evaluations on their cows.

The selection of farmers was done so that an equal number would be selected from each group, i.e., 500 each. The two groups were checked for duplication. Farmers found to be enrolled in the DHIR program were eliminated from the WI DHIA file. Then, every 5th DHIR owner and every 6th WI DHIA owner was selected. This generated a list of 1,000 farmers in each group. Only those herds containing some Holstein cattle were asked to participate in the survey. The telephone representatives kept track of how many farmers were contacted in each group. The study ended when exactly 500 farmers in each group were surveyed.

Twenty multiple choice questions were asked. Differences among responses by the two different groups of farmers were tested for significance. Questions with multiple answers that measured a gradient response (e.g., not important, somewhat important, and greatly important) were tested with a Mantel-Haenszel Chi-Square statistic, otherwise a conventional Chi-Square test was performed (5). Significant differences ($p<.01$) are designated with an asterisk. The survey and the corresponding responses were as follows.

GENETIC EVALUATION SURVEY

Hi, my name is ______________ and I'm calling from the Holstein Association. We're doing a survey to determine dairy producers' attitudes and desires regarding genetic information and the frequency of genetic evaluations. May I ask you a few questions on this topic?

* 1. Do you make your semen purchases:

a. throughout the year as needed?
DHIR herd 58%, WI DHIA herd 68%

b. primarily after new bull proofs are published?
DHIR herd 27%, WI DHIA herd 22%

c. both answers a and b
DHIR herd 15%, WI DHIA herd 10%

* 2. Do you generally buy semen:

a. from a particular AI stud or small group of studs?
DHIR herd 22%, WI DHIA herd 44%

b. from whatever AI studs have the bulls you desire to use?
DHIR herd 75%, WI DHIA herd 53%

c. both answers a and b

DHIR herd 3%, WI DHIA herd 3%

* 3. How important are the Predicted Transmitting Abilities for production and type (or PTA's) of a bull in deciding whether to use him?

a. Very. DHIR herd 78%, WI DHIA herd 64%
b. Somewhat. DHIR herd 20%, WI DHIA herd 33%
c. Not. DHIR herd 2%, WI DHIA herd 3%

* 4. A. Approximately how many animals do you sell each year for dairy purposes?
DHIR herd 13.6, WI DHIA herd 7.7

* B. How important are their PTA's in determining how you price your cattle?

a. Very. DHIR herd 33%, WI DHIA herd 18%
b. Somewhat. DHIR herd 49%, WI DHIA herd 59%
c. Not. DHIR herd 18%, WI DHIA herd 23%

5. When purchasing "seed stock" animals, how important are Predicted Transmitting Abilities for production and type in your decision?

a. Very. DHIR herd 51%, WI DHIA herd 48%
b. Somewhat. DHIR herd 36%, WI DHIA herd 33%
c. Not. DHIR herd 13%, WI DHIA herd 19%

* 6. Do you market embryos?
Yes. DHIR herd 21%, WI DHIA herd 8%
No. DHIR herd 79%, WI DHIA herd 92%

* 7. Have you ever sold a bull to an AI stud?

Yes. DHIR herd 40%, WI DHIA herd 11%
No. DHIR herd 60%, WI DHIA herd 89%

* 8. a. Do you superovulate cows and heifers in your herd?

Yes. DHIR herd 43%, WI DHIA herd 27%
No. DHIR herd 57%, WI DHIA herd 73%

b. (If yes) Which criteria do you use in selecting such animals?

! Actual production?

Yes. DHIR herd 92%, WI DHIA herd 97%
No. DHIR herd 8%, WI DHIA herd 3%

! Predicted Transmitting Abilities for type and production?

Yes. DHIR herd 91%, WI DHIA herd 92%
No. DHIR herd 9%, WI DHIA herd 8%

! Classification score?

Yes. DHIR herd 97%, WI DHIA herd 91%
No. DHIR herd 3%, WI DHIA herd 9%

* 9. How frequently do you intentionally delay breeding an animal until new bull proofs are available?

a. Often. DHIR herd 1%, WI DHIA herd 1%
b. Somewhat. DHIR herd 23%, WI DHIA herd 12%
c. Never. DHIR herd 76%, WI DHIA herd 87%

* 10. How satisfied are you with having the genetic evaluations of your 2-year olds calculated twice per year?

a. Very. DHIR herd 51%, WI DHIA herd 39%
b. Somewhat. DHIR herd 44%, WI DHIA herd 51%
c. Not. DHIR herd 5%, WI DHIA herd 10%

11. How much would more frequent genetic evaluations improve your merchandising opportunities?

a. Greatly. DHIR herd 5%, WI DHIA herd 3%
b. Somewhat. DHIR herd 48%, WI DHIA herd 40%
c. None. DHIR herd 47%, WI DHIA herd 57%

* 12. What is your primary source of genetic information?

Breed Association. DHIR herd 31%, WI DHIA herd 12%
AI Studs. DHIR herd 27%, WI DHIA herd 50%
Dairy Magazines. DHIR herd 5%, WI DHIA herd 12%
Breed Association & AI Studs. DHIR herd 14%, WI DHIA herd 9%
Breed Association & Dairy Mag. DHIR herd 3%, WI DHIA herd 1%
AI Studs & Dairy Magazines. DHIR herd 2%, WI DHIA herd 3%
All three sources. DHIR herd 19%, WI DHIA herd 12%

13. a. Do you find it EASY or DIFFICULT to keep up with the genetic information on your own animals?

Easy. DHIR herd 76%, WI DHIA herd 74%
Difficult. DHIR herd 24%, WI DHIA herd 26%

b. Would it be EASIER or MORE DIFFICULT to keep up with the genetic information on your animals if genetic evaluations were calculated more frequently?

Easier. DHIR herd 61%, WI DHIA herd 62%
More Difficult. DHIR HERD 39%, WI DHIA herd 38%

14. a. Do you find it EASY or DIFFICULT to keep up with the genetic information on AI bulls?

Easy. DHIR herd 72%, WI DHIA herd 71%
Difficult. DHIR herd 28%, WI DHIA herd 29%

b. Would it be EASIER or MORE DIFFICULT to keep up with genetic information on AI bulls if genetic evaluations were calculated more frequently?

Easier. DHIR herd 52%, WI DHIA herd 59%
More Difficult. DHIR herd 48%, WI DHIA herd 41%

15. Genetic evaluations are currently calculated twice each year. Would you find more frequent genetic evaluations:

a. Very useful? DHIR herd 12%, WI DHIA herd 13%

b. Somewhat useful? DHIR herd 57%, WI DHIA herd 58%
c. Not Useful? DHIR herd 31%, WI DHIA herd 29%

16. How frequently would you like the genetic evaluations to be calculated and made available to breeders?

Weekly	DHIR herd 0%, WI DHIA herd 0%
Monthly	DHIR herd 2%, WI DHIA herd 4%
Every 3 months	DHIR herd 51%, WI DHIA herd 49%
Every 6 months	DHIR herd 43%, WI DHIA herd 43%
Once per year	DHIR herd 4%, WI DHIA herd 3%

17. How useful would more frequent genetic evaluations of bulls be under the following situations:

a Bulls just getting their first milking daughters?

Very.	DHIR herd 46%, WI DHIA herd 42%
Somewhat.	DHIR herd 42%, WI DHIA herd 51%
Not.	DHIR herd 12%, WI DHIA herd 7%

b. Bulls just getting their first group of second-crop daughters?

Very.	DHIR herd 59%, WI DHIA herd 54%
Somewhat.	DHIR herd 36%, WI DHIA herd 40%
Not.	DHIR herd 5%, WI DHIA herd 6%

* 18. a. How many cows are you currently milking?
DHIR herd 89.4, WI DHIA herd 64.7

* b. How many of those are registered?
DHIR herd 63.9, WI DHIA herd 30.7

* 19. a. Do you own a personal computer?

Yes.	DHIR herd 43%, WI DHIA herd 34%
No.	DHIR herd 57%, WI DHIA herd 66%

* b. Do you own a modem?

Yes.	DHIR herd 21%, WI DHIA herd 10%
No.	DHIR herd 79%, WI DHIA herd 90%

c. (If no) Are you considering buying a PC/modem?

Yes.	DHIR herd 36%, WI DHIA herd 33%
No.	DHIR herd 64%, WI DHIA herd 67%

20. In which age category do you fall?

under 35.	DHIR herd 27%, WI DHIA herd 34%
36 - 50.	DHIR herd 47%, WI DHIA herd 44%
over 50.	DHIR herd 26%, WI DHIA herd 22%

Thank you very much for your time and input. We appreciate your cooperation.

DISCUSSION

The survey accomplished three objectives; it assessed the frequency at which farmers prefer to receive new genetic evaluations, it identified the primary reasons of interest in more frequent genetic evaluations, and it measured some of the characteristics associated with two different groups of farmers.

Our initial characterization of the two groups was correct. The DHIR herds place more emphasis on marketing dairy animals. These breeders place more emphasis on PTAs when deciding whether or not to use a particular bull, and in determining how to price their cattle. They sell more animals for dairy purposes, and they utilize embryo transfer, market embryos and sell bulls to AI studs more frequently.

The higher number of animals sold for dairy purposes can largely be explained by differences in herd size. The DHIR herds averaged 89.4 milking cows and sold 13.6 (15.2%) animals annually. The WI DHIA herds averaged 64.7 milking cows and sold 7.7 (11.9%) animals annually. The DHIR herds have 71.5% registered cows and the WI DHIA herds have 47.4% registered cows. Nationally, 42% of the sire identified cows on official DHIA testing programs are registered.

The DHIR herds were more likely to own a computer with a modem. However this means of communication is currently at a low level of usage, so a considerable increase in utilization will be necessary for this to become the primary means of distributing genetic information. The primary sources of genetic information for the DHIR herds are the Holstein Association and the AI studs. The WI DHIA farmers were much more likely to purchase semen from a small number of studs and depended much more upon the AI studs for genetic information. The DHIR herd owner was more likely to purchase semen from which ever studs currently have the top bulls.

Both groups of farmers had an interest in more frequent genetic evaluations. Seventy percent of the farmers answered that they would find more frequent genetic evaluations either somewhat or very useful. When asked specifically how often they would like to receive genetic evaluations, the most frequent response was every three months. There is more interest in monitoring genetic evaluations of bulls than cows (question 3). The primary time of interest is when a bull is just getting his first group of second-crop daughters. A lot of interest was also expressed in the young bulls who are getting their first milking daughters. One of the debates within the dairy industry is likely to revolve around whether the controllers of the bulls will be willing to make this volatile information public knowledge.

Although many farmers think that more frequent genetic evaluations would be useful, fewer believe that more frequent evaluations would make it easier to keep up with genetic information (question 13). They believe that it would be easier to keep up with their own cows' genetic information than with the bulls. With the low percentage of farmers indicating that they have a computer with a modem, the only apparent option would be more frequent written communication.

Obtaining more timely information on two year olds is somewhat important (44% to 51%), but few farmers (5% to 10%) found it very important. Wisconsin DHIA herd owners found timeliness of two year old information more important than DHIR herd owners. Presumably they are ready to make a quicker culling decision on first lactation cows than the DHIR herd owner.

Frequency of genetic evaluations influences timeliness of breeding. Thirteen to twenty four percent of the breeders would sometimes intentionally delay breeding an animal until the new bull proofs are available. This practice is more prominent among the DHIR herd owners. More frequent genetic evaluations may provide some improvement in marketing cattle; 43% to 53% believed it would improve merchandising opportunities.

The survey results indicate that there is interest in more frequent genetic evaluations. The reason for this is that farmers believe that more frequent genetic evaluations would be useful as opposed to making decisions easier. Receiving genetic evaluations every 3 months is the most preferred interval. Little interest was expressed for receiving genetic evaluations monthly. Few farmers currently have computers with a modem. If significant genetic improvement is to be made by providing genetic evaluations more frequently than every 3 months, and it is determined that electronic communication should be the primary means of communication, then a significant amount of education and training will be needed to successfully move from the current biannually printed delivery system to a continuous electronic communication delivery system.

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Continuous Evaluation in Dairy Cattle: An A.I. Industry Perspective - I

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With modern computers, the ability to rapidly process masses of data has revolutionized sire evaluation. Because of the tremendous mass of data available on the U.S. national dairy herd, until recently it has required the use of very large "mainframe" computers and with the advent of the Animal Model it was even necessary to employ a "supercomputer" to get the job done. Thus the frequency of running new evaluations has been limited. Now advances in data handling techniques and computer hardware have greatly shortened the computing time needed for each evaluation making it possible to consider more frequent evaluations than the traditional two per year. Others participating in the symposium will address the technical computational aspects of frequent summaries and I will thus try to cover areas that impact the A.I. industry from a decision making and marketing viewpoint.

I expect from the academic or "nice to know" standpoint continuous, even daily, sire summaries and cow evaluations would be an ultimate goal. There is, however, in addition to any decision making and marketing considerations a cost involved in making data available to AIPL. In addition, there is a cost for AIPL computing time, if not direct at least in reduced time for other research. This cost will of necessity be borne by the dairy producer either through additional DHIA costs or increased semen costs. Will any possible more rapid genetic improvement from continuous evaluation offset their additional costs?

In any evaluation process, the major effect of including new data will be on those individuals in the population with little or no previous performance data. Thus, bulls getting their initial summaries, bulls whose first "second-crop" of daughters are beginning production and cows getting their first "index" are the major groups to be concerned with. Experience has shown that early summaries based on relatively few daughters, with in-progress records are very volatile. In a study of the January, 1991 USDA Summary involving the top 10% of first summary bulls at Select Sires, the average change for this group of bulls was -475M with only one bull retaining his top 10% ranking among this same group of bulls on the July, 1991 Summary. Unfortunately, my observation over many years is that this volatility on early data is not unusual. Thus, frequent evaluations of sires at early stages will result in many ups and downs in the PTA values. At this early stage an A.I. organization, if prudent, only makes a decision to collect or not collect semen and delays the marketing decision until a later date. Usually, we have no choice in this delay simply because there is not enough semen available to begin a marketing effort on the sire.

Can the decision to begin collecting semen be made earlier with frequent evaluations? The answer depends on the organization and its structure to provide feedback on the early daughters of a bull. In most A.I. organizations I expect there is an informal feedback from salesmen and those evaluating the daughters' type which identifies the truly superior sire at a very early stage. At Select Sires the decision to collect semen is made based on a combination of available space, parent average (PA), field reports, and latest sire summary. Frequently a sire will be placed "on collection" based on his PA and a few reports from field personnel.

At what point should the decision to market semen be made? After two consecutive summaries with increased PTA's? What do we do when next weeks or next months summary shows a lower PTA? The answer will be addressed later in the discussion on marketing.

Typically in the A.I. industry a sire is given limited use in a sampling phase and then not used for several years until a genetic evaluation based on progeny is available. If judged superior enough, the sire is marketed as a proven sire. Two and a half to three years later a large group of new daughters begin providing data for a reevaluation of the sire. When this large volume of data begins to enter the sire summary usually some of the very first records are abnormal, being produced by daughters that calve at very young ages or abort a calf too close to normal gestation length to be coded an abortion. Unless sufficient time is allowed for a more normal group of daughters to produce data, the variations in PTA's can be substantial and are usually negative. Thus, the inclusion of this early data tends to cause dairymen to stop using bulls that are genetically superior as well as undermining their confidence in the sire summary evaluation.

On the cow side, there exists possibly the strongest argument in favor of more frequent genetic evaluations. Today, under the 2X per year format some cows will receive initial PTA's after only two months production while others will have eight months recorded. Although when considering the time delay from the cut-off of records for forwarding to AIPL by the various DRPC's the actual evaluations are available when cows have been in production for 5 to 11 months. Possibly the calculation procedure can be shortened? If an initial cow evaluation is to have value it must be available before the cow is to be rebred, since once she is pregnant all need for speed of evaluation is delayed for at least nine months. Thus to be of value, except to a very small percentage of merchandisers, the cow PTA must be available within 60 days of her calving, which in practice means PTA's based on first sample day, calculated and delivered to the industry within 30 days. Is the first sample day that reliable? From a practical standpoint a significant percentage of cows contracted to A.I. today are either virgin heifers or have only calved once. For example, at Select Sires 25% of current mating contracts are virgin heifers and approximately 50% have had only one calf. Therefore, even under a continuous evaluation system no PTA would be available at the time the mating contract is negotiated.

Obviously, to affect genetic improvement semen from the most superior bulls must be marketed so that it is available to breed cows. Now let's look at the ramifications that continuous evaluations may have on semen marketing. In order for a sire to be marketable he must produce a sufficient volume of semen and his semen must be in the possession of the salesman making the sale, in other words, there must be sufficient volume and time to fill the "pipeline". In most A.I. organizations operating today, it takes several months for a normal healthy sire to produce this base amount of semen required. In practice at Select Sires most bulls require nearly six months to produce the amount of semen desired for initial marketing; however, I recognize smaller organizations may not require as much lead time. The point is that increasing the frequency of calculating sire summaries has no effect on the physiological capability of a sire.

How does a dairyman make his decision on the sires from which he is going to buy semen? Those of us with advanced degrees in genetics might expect him to sit down determine what traits are most needed in his cow herd, analyze sire PTA's for production and type, consider the semen price and make his decisions. While many progressive dairy producers have on farm computers and a very small proportion are "on line" with DRPC's taking time and spending money to access the data base for the latest sire ranking every time a semen salesperson calls on them will simply not be done. The fact is that most semen purchases are made based on some type of literature that is available and/or the salesmanship of the last salesperson in the barn.

With frequent updating of genetic evaluations printed information would nearly always be out of date. A.I. organizations invest millions of dollars in producing printed material and advertising in the agricultural press. With a shortened "shelf" life of this material large amounts of money must be spent to update and keep it current. If you question the lead time involved refer to the issue date of the magazines in which you first saw the January sire summaries. The dairy producer who does carefully analyze the data on the sires he purchases tends to look for stability of proofs and doesn't make quick decisions. If by the time he is ready to buy, new PTA's are available, he will gravitate toward higher reliability sires because he is more comfortable with them. This would thus slow down the acceptance of new, higher PTA sires and reduce genetic progress. While several dairy geneticists have done considerable work on portfolio selection and it has had some exposure in the popular press, the vast majority of dairy producers buy and use individual sires.

The National Association of Animal Breeders (NAAB) has focused considerable energy on guidelines for the publication of sire evaluations in order to assure dairy producers that the data being presented is the most current available. With the present, well defined system of biannual summaries, I think the industry's record in this regard is very good, even though occasionally there appear to be situations where the newer data was omitted if it was not as favorable. I seriously wonder if the record would be as good with constantly changing evaluations.

One additional cost that must be addressed is that of staff time in the decision making process of which bulls to market and how to price their semen. In our own situation at Select Sires, we had 345 bulls on our "decision" list when the January sire summaries arrived. To process, assemble and analyze the data on 20 to 25 different traits for this large a group of bulls is a formidable task. The extra time required to do this on a more frequent basis would cause other responsibilities to be delegated to others, which translates into additional staff and therefore additional cost which must be passed on to the dairy producer.

Frequent genetic evaluations are an interesting exercise for the very small portion of the dairy industry that is particularly attuned to studying them. In practice they will:

1. Increase the cost to dairy producers due to the necessity to more frequently forward data to AIPL.

2. Significantly increase the expenses of A.I. organizations in promoting and marketing of semen and thus increase the cost of semen to dairy producers.

3. Likely increase the reliance of dairymen on "Reliability" to avoid constantly changing PTA values thus slowing down the use of new sires. This would in effect slow down genetic progress.

4. Provide an "always changing" climate, which would give dairy producers less confidence in the size summaries. With heat detection a problem anyway, their use of a herd bull could be more likely.

5. With a significant percentage of matings to produce future sires being made before any type of index including a cows own performance could be available a change in the frequency of evaluation would have little positive effect on the selection of sires for sampling in A.I.

6. Make little or no change in the number of units of semen eventually marketed from the most superior, high demand sires. The major effect would be substituting one low demand sire for another one.

7. While there are a few advantages of frequent sire summaries for a minority of the dairy industry, its adoption would be analogous to adding an interchange at every crossroad to a very functional interstate highway. It would be easier to get on and off but the whole system would be slowed down.

The proceeding comments address the effect of continuous evaluation on domestic dairy cattle breeding. Today most A.I. organizations also derive significant income from the international market. Rapidly changing evaluations combined with longer lead time for decisions usually noted in the international market would complicate marketing in this important market. Of particular consequence is the need to complete specific health tests for each semen order in some markets. As an example, to export semen to some markets sires must be isolated for several weeks and only semen collected in specific time windows and/or facilities will qualify.

Now that Canadian data is being used in USDA Sire Summaries, will new data be available from Canada monthly and/or weekly? With semen imports expected from Europe within a year, how soon will European data be included and how frequently will it be available?

Continuous Evaluation in Dairy Cattle: An AI Industry Perspective - II

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Marketing is not an exact science with a single best solution to each problem. Several marketing strategies may achieve similar results by different routes.

The marketing staff at American Breeders Service has identified many advantages for more frequent evaluations, including:

1. More current and reliable information, which permits more effective recommendations for matings.
2. Enhanced marketability of value-added products.
3. More reasons to call on customer with something new and positive to discuss.
4. Sales calls that focus on positive developments.
5. Representatives in the role of a sustaining resource for the customer rather than as a product peddler.
6. Reduced expenditure for expensive colorful sire directories.
7. Distribution of sales efforts more evenly across the year.
8. Earlier alerts that a bull's data may be developing unfavorably so that sales efforts can be reduced.
9. Earlier marketing of new bulls with promising information.
10. Earlier stockpiling of semen from promising candidates with preliminary data.

In addition, the sire development staff has identified other reasons why more frequent evaluations would be favorable:

1. More accurate evaluations for new young sires (compared with AI organizations' preliminary evaluations) because of:
   a. More complete data.
   b. More appropriate assignment of herdmates.
   c. More accurate analysis.
2. Earlier evaluation of young sires, which permits:
   a. Earlier culling.
   b. More effective use of housing.
   c. Shorter generation interval for sires of sons.
   d. Earlier start on photographing daughters of best prospects.

3. More accurate genetic evaluation of heifers and young cows, which permits shorter generation intervals and better bull dams.

4. More complete access to daughters of young sires.

5. Reduced cost and hassle of gathering preliminary records from dairy records processing centers (**DRPC**) because of discontinuation of AI organizations' preliminary evaluations:

    a. Record release authorizations from test herds and DHI rejections because of:

        (1) New name for herd.
        (2) Changed DHI number.
        (3) New mailing address.
        (4) Misspelled name.
        (5) New owner or partner.
        (6) Other.

    b. Data from nine DRPC:

        (1) Different arrival times.
        (2) Different herdmate comparison procedures.
        (3) Different formats.
        (4) Costly duplication of effort at DRPC and at AI organizations.

In summary, more frequent evaluations would deliver a better product to dairy producers, simplify AI organization operations, reduce costs, improve efficiency of operations, increase the rate of genetic improvement, and make US dairy cattle more competitive in the world market.

Abbreviation key: DRPC = dairy records processing center

Continuous Evaluations in Dairy Cattle: An AI Perspective - III

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INTRODUCTION

From an AI standpoint, there are many issues to be considered when determining the significance of continuous evaluations (CE) to the dairy industry. Different viewpoints have been expressed from the genetics, marketing, and advertising and promotion divisions of the AI industry, as well as across AI organizations. As with any implementation of new technology, unanimous approval is impossible, yet all factors must be considered to determine what is the best and most feasible solution for the entire dairy industry.

MISCONCEPTIONS

First of all, there is a need to address a few common misconceptions about CE. CE will not cause distribution of new PTAs on all bulls to dairy producers weekly, or even monthly. This would not make much sense under the current system of data transfer, since the turnaround time for receiving information from the field and releasing evaluations is over two months. A more realistic approach would involve frequent access to new evaluations by owners of the animals, but release only of animals above a certain threshold, on a less frequent basis. A pre- defined subset of animals would most likely be released each time, with full releases as usual in January and July. Possible subsets of animals to be included in the interim releases have yet to be determined, although some suggested possibilities are:

1. Animals with no previous PTAs.
2. Animals whose change from the previous evaluation is above a certain threshold.
3. Heavy impact bulls and cows, such as the top TPI list.
4. Bulls adding second crop information.

Would USDA and the Holstein Association (HFA) be allowed to release new PTAs on animals to their owners, even though this information would not be made public? This is a strong possibility, since this is already being done to some extent. Most of the studs (AI organizations) do their own in-house preliminary evaluations (PE) on low reliability bulls now. This information comes indirectly from dairy producers, through data records processing centers (DRPC), and this preliminary information is retained by the stud.

What about huge increases in advertising and promotion costs for AI organizations? For the most part, bulls with no previous evaluation would not be marketed immediately after the interim evaluations, but would be put into semen collection. The most probable proposals for release of currently active bulls would limit the number of these released so that the total number of active bulls included in the interim release could be around fifty for all AI organizations. This small number of bulls could easily be addressed with small, relatively low-cost fliers. Many of the studs are already using this form of media to deliver information to their customers between current evaluation releases.

One of the biggest hurdles for CE is the fact that many people feel that the additional costs of more frequent evaluations will be passed on to dairy producers. As of this date, I have seen no financial analysis on the effects of CE on the dairy industry as a whole. Certainly there is a cost associated with CE, but it has not been determined yet as to the magnitude of these costs. Nor has it been shown that these costs will not be offset by the benefits of increased genetic gains, increased efficiency, and decreases in other costs, which CE has to offer.

How would CE deal with bulls from Canada with daughters in the US, whose information has recently been incorporated into USDA evaluations? A possible solution for now would be to use previous Canadian information and current US information. These bulls would be included in the interim release only if they met the criteria for the proposed subset of interim release bulls. In the future, Canada may go to more frequent evaluations, and USDA may look into obtaining this information more frequently at this time.

ADVANTAGES

Probably the biggest advantage of CE to AI is its replacement of current PEs done by most studs. Although some are against CE, most studs already are dealing with more frequent evaluations for production and type. Since the six month interval is too long for important decisions that must be made, Landmark does four PEs per year to use in semen collection, culling, daughter picture, and sales decisions. These are decisions that can't be made just twice a year. Most other studs are calculating PEs at least this frequently.

Landmark currently gets records-in-progress (RIP) from all nine data record processing centers (DRPC) four times a year. Since the cost of getting all herdmates is too high from most DRPCs, deviations calculated by the DRPCs are used in the PE calculations. Several different definitions of 'herdmates' are used by the DRPCs, none of which are close to that used by USDA. As a consequence, inaccurate estimates of true herdmate deviations are obtained, and the deviated records from all DRPCs need to be adjusted before they can be used in the PEs. The accuracy of these PEs are severely reduced by these alternative deviations. In addition, this information comes in several different, sometimes unstable, formats, which increases labor costs to AI.

Landmark spends in excess of $10,000 annually on these PEs, yet this is a good investment since we can use it to determine what bulls to put into semen collection. If ample semen is available on the bulls, they can be marketed immediately following the next sire summary. We can also use this information to determine what daughters need to be pictured for use in promotional materials. Several of the other studs are spending at least this much on PEs for the same reasons, and will most likely continue to do so as long as there are only two evaluations per year, because they see equal or greater return on their investment.

Since the AI industry is already spending this much on PEs, much of this money could be put towards the additional cost of CE. This would replace any income that DRPCs would lose if studs no longer require these RIPs directly from the DRPCs. Sending RIPs to USDA monthly would be more efficient for both the DRPCs and the studs, since the DRPCs would need to send their RIPs to only one source instead of many, and studs would receive interim evaluations from one source instead of many.

The accuracy gained by receiving multiple interim releases could eliminate the need for PEs in most cases. Official interim evaluations would be much more valuable to AI than current PEs. Other information routinely obtained from RIPs from DRPCs, such as location of milking daughters could potentially be gotten from USDA, but the location of replacement females might still have to be obtained directly from the DRPCs.

More frequent evaluations could help increase the sales of bulls with favorable information in the interim releases. Timing is everything in semen sales, especially now with the accelerated replacement of current high bulls with new younger bulls, due to genetic trend. With some exceptions, a bull can only be marketable for so long before younger bulls will surpass him in the rankings. Therefore, it is of utmost importance to have semen and promotional material ready to go on new marketable bulls as soon as possible. CE would give studs a headstart on these bulls in order to get them ready to release with the regular January or July evaluations. A several month lead time would be enough for Landmark to get most bulls ready to release in January or July.

Granted, most studs are using their PEs to get an early start on preparing future marketing bulls already. However, the low accuracy of PEs causes a lot of inaccurate predictions of future marketing bulls. Some bulls are collected that will never be marketed, and other bulls are not collected although they would have been marketed had there been semen available. This inaccuracy of PEs causes increased AI costs due to excess semen inventories and lack of semen available for marketable bulls.

CE could also be used as a marketing aid for current active bulls. Interim evaluations could be used to determine future marketing techniques and collection schedules for these bulls. Bulls with higher interim evaluations can be pushed harder both in the sales and collection arena. Bulls with lower interim evaluations can be marketed with lower intensity and taken out of semen collection to decrease costs of excessive semen inventories.

More efficient culling of bulls is another advantage of CE. Currently at Landmark, bulls are culled every six months after the sire evaluations. Inaccuracy of PEs does not encourage interim culling of bulls. CE would allow us to cull bulls many times per year, decreasing housing costs and housing shortages. This translates into better semen prices for dairy producers.

A discussion on CE is not appropriate without the mention of the genetic gain associated with CE. While all bulls contribute to the overall genetic gain of the population, mating sires have the most impact on future genetic gain. Due to the steady genetic gain in current dairy cattle populations, relatively low reliability bulls are heavily used as mating sires. Typically, these new bulls are used heavily right after proofs, and rumors about the future evaluations of these bulls circulate for the next six months, with much effect on the usage of these bulls. Under CE, we could know the bulls actual evaluation much sooner, and could continue heavy usage or quit using the bull as a mating sire at this time.

Over the years, many sires have been used heavily on the cow population, only to drop significantly six months later. If we could pinpoint these bulls earlier, we could avoid including descendants of these bulls in sampling programs through several pathways:

1. Avoid using these sires for further contract matings.
2. Avoid using daughters of these sires for further contract matings.
3. Avoid sampling any sons of these bulls already in the system.

These pathways cover bulls of all ages, from those with just one evaluation to those just receiving second crop information.

If you consider mating sires used since July 1989, there have been many examples of sires that dropped considerably in six months, and did not revert to their original level. Had this information been known several months earlier, they or their offspring would not have been used in additional contract matings. Matings to these bulls done during this six month time period resulted in young sires that were sampled in AI and are sires-in-waiting at many studs. Since these young sires have a reduced chance of making any active lineup, this will cost the AI industry a great deal.

Conversely, there were also several examples of bulls whose evaluations climbed considerably in six months. The use of these bulls a few months earlier would not increase genetic gain much by itself. However, these bulls would have been used as mating sires instead of the bulls that dropped. This combination would have resulted in a considerable genetic gain for the population, as well as decreased costs for AI. This translates into lower semen prices and increased income for the dairy producers.

One side issue that has not been previously addressed in conjunction with CE, but has recently become more closely associated with CE, is the release of error lists. Error lists are lists generated by USDA that include females that were not included in USDA evaluations due to some inconsistency in their data. Error lists are currently released in December and June by USDA and are becoming more accessible so that daughters that are not included in a bull's evaluation could be corrected and be included in a later evaluation. A more attractive goal, however, would be to get these error lists every month so that daughter records could be corrected in time to be included with the bull's upcoming evaluation. Since some DRPCs are already sending RIPs monthly, this seems like an attainable goal that would be reached even without CE. The implementation of monthly error lists would encourage DRPCs to send monthly RIPs, improve efficiency of data transfer, and decrease the costs attributable to CE.

DISADVANTAGES

One of the main arguments against CE seems to be the cost of implementation. The DRPCs would incur additional costs by sending RIPs to USDA more frequently. USDA and HFA would incur additional costs by running more evaluations per year. AI organizations would have to invest more money in advertising and promotion. The question still remains as to who will absorb these costs and if they will be passed on to dairy producers through increased prices for semen and data collection.

The sending of RIPs to USDA monthly will help in generating monthly error lists, which would be a benefit to dairy producers, DRPCs, DHIA, studs, and breed associations. This valuable tool should help offset some of the costs of CE. The increased efficiency of data transfer within the industry, along with the increased value of the data received, should help make CE more feasible.

Increased advertising and promotion costs are a certainty, but Landmark already sends several interim promotional fliers, as do many of the other studs. The amount of information from the interim releases that would need to be distributed could easily be handled in the same manner. International markets pose more of a problem, however, since these markets require more time to disseminate information at a greater cost. Since these markets are too important to ignore, possible solutions need to be considered. On the other hand, data transfer to most of these markets is only a FAX away.

These increased promotional costs could be absorbed, however, through reduced sire procurement costs and lower semen inventories. Due to more accurate rankings of high sires, the percentage of young sires that make marketing lists could be increased. The efficiency of semen collection would be greatly enhanced so that truly superior bulls could be put into collection earlier and bulls currently overevaluated by PEs would never be collected.

Another problem involves the release of interim PTAs. The release of animals with no previous PTAs only to their owners should not pose a problem. The additional subset of animals designated for interim release, however, is a more controversial topic. Should owners be allowed to access preliminary evaluations of these animals, without public release? Certainly these are issues that need to be answered before the implementation of CE, but they do not discourage the use of CE. From an AI standpoint, the value of CE would be decreased if information on bulls with previous evaluations would not be released to the owners.

Another question that has been raised about CE is the possible 'yo-yo' effect of evaluations over time. With more frequent evaluations, sire evaluations may change several times a year instead of two, causing more confusion among users of this information. A bull that previously showed no change in six months may go up in interim evaluations and then fall back to the original level. From an end-users standpoint, more change causes more skepticism in the evaluations and less chance of using lower reliability bulls, which historically change the most. However, since only a subset of bulls with previous evaluations might be released, nobody will ever see these ups and downs, unless the bulls change a great deal each time.

FEMALES

There has not been much mention of the effect of CE on females in this paper. The benefit to females is of less importance to the dairy industry than that for males for several reasons. First of all, most producers will not benefit greatly from more frequent evaluations of their females. While seedstock producers will definitely benefit from CE, the dam of bull pathway does not have an effect of the same magnitude on future genetics as does the sire of bull pathway. In addition, while all dairy producers can benefit from CE of bulls through direct access to AI sires, the same is not true of elite females.

The main benefit to the female side would be earlier detection of elite females through earlier PTAs. However, the increasing use of virgin heifers as dams of young sires has diminished the potential of this benefit. Over half of the contract matings done at Landmark are to virgin heifers, with other studs following similar trends. Therefore, many of the females that would get initial interim evaluations would already have sons entering AI. While some true outlier individuals would be found earlier through CE, the effect would be lower than that found on the sire side.

CONCLUSION

Certainly, much discussion and education is needed before a consensus can be reached on CE. Input is needed from all facets of the industry, including dairy producers, AI, DHIA, DRPCs, breed associations, etc. There will definitely be increased costs due to more frequent sending of RIPs, evaluations, and dissemination of this information. However, there will also be the genetic reward associated with CE and decreases in other costs due to more efficient semen collection and early culling of bulls. When all is considered, there seems to be a potential gain, both genetically and financially, associated with CE. The increased efficiency associated with CE will help cut costs while creating a more valuable product to the dairy producer. CE is an important step for the US dairy industry in order for us to keep a step ahead of our competitors from outside the US.

Continuous Evaluations: a Dairy Producer's Perspective

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ABSTRACT

National genetic evaluations for dairy cattle are currently computed semiannually. Technology has advanced such that more frequent evaluations are now possible. Continuous evaluations could accelerate genetic progress, principally by reducing generation interval. In general, dairy producers are more interested in sire evaluations than cow evaluations. Dairy producers are particularly interested in a bull's evaluation when the bull is adding first-crop daughters and again when the bull is adding second-crop daughters; these are the two times when a bull's evaluation is most volatile. If additional daughter information suggests that a bull's evaluation is declining, dairy producers will want to modify semen purchases accordingly.

Continuous cow evaluations will be of little interest to commercial dairy producers, but will be of high interest to breeders of seed stock. Continuous evaluations would allow elite young cows that are bull-dam candidates to be located sooner. Management reports that incorporate updated genetic information could also be helpful for dairy producers when they make culling decisions for cows, heifers, and the semen tank.

Easy-access and low-cost delivery systems to disseminate genetic information to dairy producers more frequently would need to be developed. Producer access to information by computers will continue to grow. Most dairy producers have access to computers either on their farm or through agriculture professionals and consultants. Breed associations, Dairy Herd Improvement, and artificial insemination organizations also are likely to develop new information delivery systems.

Dairy producers are used to making management decisions daily based on new information. If continuous evaluations were implemented, most dairy producers will probably adapt quickly to more frequent genetic information, although the possibility exists that some dairy producers will find the additional information overwhelming. If more current and accurate genetic information is available, dairy producers will want to incorporate this information into their breeding programs as quickly as possible.

Industry discussions on equitable payment for dairy records and information may become more of an issue with continuous evaluations. Ultimately, the costs associated with continuous evaluations will be passed down to the dairy producer. Dairy producers will have to be convinced that the benefits associated with continuous evaluations are greater than the costs required to calculate and disseminate the information on a more frequent basis.

INTRODUCTION

Since 1978, dairy producers have come to accept semiannual genetic evaluations for dairy cattle in the United States as the industry standard. Prior to 1978, evaluations were calculated three times annually. Tremendous progress has been made in the past 15 years in both computer technology and computing strategies. Evaluation procedures that were cost prohibitive 15 years ago can now be conducted relatively inexpensively, as discussed by Misztal (5). This paper will assume that access to data and expenses associated with computation are not limiting factors. However, even if data collection and computation are economically feasible, an information delivery system has to be developed that permits dairy producers quick, easy, and low-cost access to updated evaluations. Disseminating more frequent genetic information to the end user will require development of more sophisticated delivery systems than are currently in place (5). Delivery mechanisms must be an integral part of the discussion of continuous evaluations. Several possibilities will be discussed.

Another challenge for this paper is trying to convey a dairy producer's perspective. Dairy producers are not a homogeneous group. For example, most dairy producers who merchandise breeding stock may be quite interested in continuous evaluations, whereas commercial dairy producers who primarily sell milk will likely be less interested in continuous evaluations. However, this difference in interest level between merchandisers and commercial producers already exists with the current semiannual evaluations. The challenge for the dairy industry will be to determine if the beneficial aspects of continuous evaluations outweigh the costs of collecting data, computing results, and disseminating the information.

DAIRY PRODUCER'S PERSPECTIVE

Why should the dairy industry even discuss this issue? The purpose of genetic evaluations is to provide the industry with breeding tools to assist with selection of breeding stock. The ultimate goal is to accelerate genetic progress. The central question, therefore, is "Can continuous evaluations help accelerate genetic progress?" If continuous evaluations are not going to accelerate genetic progress, then there is little justification for implementing the procedures. How can genetic progress be increased by continuous evaluations?

The classic animal breeding formula for genetic change is listed below:

$$\text{genetic change} = \frac{\text{F(accuracy of selection x intensity of selection x genetic variation)}}{\text{generation interval}}$$

Lohuis et al. (3) estimate that continuous evaluations could accelerate annual rates of genetic progress for milk yield an additional 7 to 9% compared to current rates observed with semiannual evaluations; they propose that continuous evaluations would have their biggest impact on genetic change by reducing generation interval, particularly the dam of sires pathway. Dairy producers cooperating with AI organizations to produce breeding stock would utilize the updated genetic information when selecting bulls and cows to use as parents. Commercial dairy producers could take advantage of updated genetic information when selecting sires to use in the herd. Obtaining more accurate information sooner could reduce generation interval. What specific aspects of continuous evaluations will be of greatest interest to dairy producers?

Impact on Sire Selection

Dairy producers want accurate information on bulls. In particular, dairy producers are most concerned about the accuracy of a bull's genetic information at two distinct time periods in the bull's life; when his progeny-test daughters freshen (usually called first-crop daughters) and when daughters that resulted from semen sold after his progeny test freshen (usually called second-crop daughters). Studies by Misztal et al. (6) with final score type data on Holsteins demonstrated that these are the two time periods when genetic evaluations are likely to change the most.

The AI organizations in the U.S. progeny sample about 1200 young Holstein sires each year (M. Seiber, personal communication, 1992). This means that about 600 AI progeny-test bulls receive initial daughter evaluations every six months. However, the AI units distribute semen on young sires throughout the year and daughters freshen throughout the year. Some bulls may have as few as 10 daughters in their initial daughter evaluations, whereas other bulls may have 50 or more daughters in their initial daughter evaluations.

With semiannual evaluations, many of the bulls with few daughters are not released for active AI service by the controlling AI organizations until the next sire summary. The primary reason for delayed semen distribution is to allow time for the evaluation to become more accurate. After six months, more daughters will have both freshened and completed more of their first lactations. The six month's delay also gives the AI organization additional time to collect semen on the bull to meet marketing demands. The AI organizations consider the time delay between initial evaluation and release date as a kind of safeguard for dairy producers.

Dairy producers do not want to purchase semen on a bull and find out later that the bull's evaluation has declined, so waiting until the bull's evaluation has stabilized before the AI units release semen seems warranted. However, semiannual evaluations result in a flurry of activity in January and July; purchasing semen on newly released bulls with the highest evaluations is often difficult for dairy producers. Continuous evaluations would allow an opportunity for AI units to release semen on newly proven bulls throughout the year, which may help keep supply and demand in better balance. However, as discussed later, delivery systems that would allow dairy producers ready access to updated genetic information are not well developed.

As additional daughter information becomes available, a bull's evaluation will increase in reliability. An AI organization may make a decision to either include or exclude a bull to be used as a sire of sons based upon the new information. Many dairy producers follow the lead of AI organizations. If a bull is predicted to transmit outstanding genetics and is going to be used as a sire of sons, dairy producers are also going to want to incorporate these genetics into their herds quickly, particularly producers developing breeding stock.

Many of the bulls used heavily in breeding programs are bulls that have not yet received second-crop daughter evaluations. This reflects the rapid rate of genetic progress occurring in the dairy population. Rate of genetic progress in the recorded female population for cows born in 1985 through 1989 for milk yield is listed in table 1.

TABLE 1. Superiority of Holstein cows born in consecutive years for breeding value milk[1] (1).

	Breeding value milk	
Consecutive birth years	Yearly trend	Cumulative trend
	(kg)	(kg)
1986 - 1985	123	123
1987 - 1986	122	245
1988 - 1987	163	408
1989 - 1988	168	576

[1]Breeding value milk = 2 * (PTA milk).

Breeding values for the Holstein cow population has increased 576 kg in four years (1). In January, 1993, 84 of the top 100 TPI bulls in the Holstein Association's Sire Summary had reliabilities less than 95% (2). Bulls with 95% reliability or lower are those bulls with few or no second-crop daughters. Research by Meinert and Pearson (6) indicates that the average evaluation for AI-proven bulls changes little over time. This suggests that the principal reason that so few bulls with second-crop daughters are on the top 100 TPI list is that the younger bulls are higher in genetic merit and are replacing many of the older bulls on the top 100 TPI list each evaluation.

After all of a bull's progeny-test daughters have freshened, his evaluation usually changes little until second-crop daughters freshen three to four years later. When dairy producers make a decision to purchase semen on a bull with first-crop daughters, their expectation is that the bull's evaluation will not change. Even though the average change for bulls proven in AI is near zero (4,7), evaluations of individual bulls can continue to fluctuate as additional daughters freshen and complete their lactations, particularly bulls not progeny tested in AI (4). Dairy producers are mostly concerned about a bull whose evaluation declines sharply from one six-month evaluation to the next, particularly if they bred a lot of cows to this bull or paid a lot of money for the semen. Dairy producers are less concerned about bulls whose evaluations increase from one six-month evaluation to the next. If dairy producers purchased semen from a bull that increased in evaluation, the producers usually look upon this as a bonus.

More frequent evaluations would permit dairy producers to monitor the progress of a bull's evaluation more closely at the time when much new daughter information is contributing to the bull's evaluation. This is probably more true for bulls adding second-crop daughters than for bulls adding first-crop daughters, since AI units usually delay the release of semen for bulls just adding first-crop daughters. Financial outlay for semen purchases can be tempered to reflect any new data that may suggest that the bull's evaluation is either increasing or decreasing.

Impact on Cow Selection

For most dairy producers, cow evaluations play a small role in herd management programs. Culling decisions for cows are probably based as much (or more) on phenotype than on genotype. After a cow freshens, dairy producers are generally more interested in how much milk a cow is giving rather than in her genetic merit for milk yield, particularly commercial dairy producers. Dairy producers are not likely to cull a high-producing, trouble-free cow with a low genetic evaluation.

First-crop daughters of AI progeny-test bulls are usually found in commercial herds, and most daughters are unregistered, particularly in the Holstein breed. From an industry standpoint, having more updated evaluations on these cows more frequently will have little impact on the breed. Because young sires are randomly sampled in commercial herds, few of these first-crop daughters have successive generations of elite sires in their pedigree. The AI organizations usually find prospective bull dams in herds with more designed breeding programs.

Continuous evaluations are likely to have a greater impact on daughters of bulls just receiving their second-crop daughter evaluation. Bulls are often used heavily in breeding programs shortly after their first-crop daughter evaluations. It take approximately four years before these second-crop daughters contribute to the bull's evaluation. Bulls adding second-crop daughters may add several hundred daughters to their evaluations over the course of six months.

Dairy producers who are providing breeding stock to the dairy industry are very interested in the second-crop daughter evaluations of bulls. The initial group of second-crop daughters is the group of females that is used most extensively as bull dams. With semiannual evaluations, if a first-lactation cow does not have at least 40 days in milk prior to the record cut-off date at the Dairy Records Processing Center, the cow does not receive an evaluation. The record cut-off date has been the third week in May for the July evaluation and the third week in November for the January evaluation. Consequently, a cow that freshens in May, for example, has not received an evaluation until the following January, after she has been in milk for about eight months. Powell et al. (8) reported that over 48% of the cows that were in the top 1% of the Holstein breed for genetic merit based on an economic index incorporating genetic estimates for milk, fat, and protein (MFP$) were first-lactation cows. More frequent evaluations could help AI sire analysts locate these young cows sooner and simplify the decision on whether or not these cows should be used as bull dams.

In reality, many of the AI organizations do not wait until a cow has an official evaluation before contracting the cow. The AI organizations estimate the cow's evaluation based on her pedigree and her deviations in the herd. In general, the biggest challenge for the AI industry is initially locating these cows. Continuous evaluations should allow the industry to find these elite young cows sooner. The rapid speed at which the industry locates elite young cows may become an issue for some breeders if they feel that others in the industry have easier access to genetic information on the breeders' cows than the breeders do. For example, if a breeder does not have computer link-up capabilities, the AI industry and others are likely to know the genetic evaluations of the producers cows prior to the breeder. Breeders may feel that they have not had adequate time to determine the value of animals in advance. Of course, this scenario currently exists with semiannual evaluations, but may become a larger frustration for breeders with continuous evaluations.

Culling Decisions

Continuous genetic evaluation could further assist dairy producers with culling decisions. Cows are culled throughout the year. Updated genetic evaluations on cows would be helpful to dairy producers when they are making the final decision on which cow(s) to cull. Additionally, continuous evaluations may provide an opportunity for the development of management reports that would assist dairy producers in two culling areas not traditionally considered on most dairy operations; culling of heifers and culling of the semen tank. Dairy producers who are doing a good job of herd management have been successful in reducing age at first-calving. Data from DHI herds in Wisconsin indicates that average age at first calving declines as average herd production increases. Holstein herds that average over 10,450 kg of milk per cow and under 5,900 kg of milk per cow have an average age at first calving of 26.4 months and 28.2 months, respectively (J. Pinter, personal communication, 1993). Improved calf rearing in well-managed herds has also reduced calf mortality. The combined result of more calves alive and lower calving ages in these well-managed herds has resulted in an excess of heifers.

Dairy producers who are not expanding the sizes of their operations must make a decision as to which animals should be sold, and when. In general, dairy producers do not consider the culling of unfreshened heifers. Monthly management reports which include the most recent genetic estimates of heifers would be helpful in making culling decisions for heifers. The updated genetic information, along with age, calving dates, and so forth could be input into computer software programs on culling to help determine which animals are predicted to be the least profitable across various planning horizons. Heifers that are sired by bulls whose evaluations may have declined substantially from the time when the sire was used in the herd would be prime candidates for culling. Herd owners often use bulls heavily in the herd shortly after the bulls receive their first-daughter evaluations. Consequently, heifers that are due to calve are often sired by bulls who are currently adding many second-crop daughters. Since this is a time when bull evaluations are known to change (6), dairy producers may want to consider selling some of the lower genetic-merit heifers rather than calving these heifers out.

Few dairy producers cull their semen tanks. Continuous evaluations may encourage dairy producers to more quickly cull semen from a particular bull whose proof has declined. Additionally, continuous evaluations may encourage dairy producers to monitor semen purchases more closely, particularly for bulls that may still be adding large numbers of daughters to their evaluation. Conversely, some dairy producers may interpret small changes in a bull's evaluation as distinct trends and may purchase or cull semen based on small changes that may not accurately reflect long-term trends.

Disseminating Information to Dairy Producers

Dairy producers currently have access to genetic information from the semiannual genetic evaluations through a variety of sources, including breed associations, trade magazines, DHI management reports, and AI sire directories. Some computer software programs are also available for sire selection. As discussed previously, dissemination of information to the public may be one of the biggest challenges associated with continuous evaluations. What options might exist to disseminate information to dairy producers more frequently?

Computer Access. Although on-farm computer use continues to grow, it is unrealistic to think that the majority of dairy producers will have computers on the farm in the near future. However, portable computers are becoming commonplace among agriculture professionals that visit the farm, such as veterinarians, DHI field technicians, management consultants, and AI and breed representatives. Almost all dairy producers have access to computers on their farm through their circle of agriculture professionals, if not today, certainly in the near future. Presently, few computer network systems are in place to access public databases or bulletin boards. Access to data files by computer, either by the dairy producer directly or indirectly through agriculture professionals, should be developed. Logical organizations to develop public databases or bulletin boards are DHI, breed associations, and the AI organizations.

Dairy Herd Improvement. Updated genetic information calculated by USDA and the Holstein Association is sent to DHI processing centers twice a year for both bulls and cows. Bull information is likely to be of greatest interest to DHI members. Possible management reports would be summary reports of sires currently being used as service sires. Bulls that have changed by a predefined amount could be highlighted. For example, all bulls that have declined by more than 300 pounds of milk over a two or three month period could be highlighted and would be candidate bulls for culling from the semen tank.

Management reports for culling could also be provided on a monthly basis. Incorporation of updated genetic information would be helpful for culling decisions of heifers and cows.

Most processing centers would need to develop procedures to incorporate genetic data more frequently, as discussed by Misztal (5). Individual processing centers probably have differing priorities for updating data files with more current genetic information and disseminating the genetic information to their members and customers. Unless dairy producers make a strong request that updated information is needed for management purposes, the processing centers will have limited motivation to modify existing procedures.

Breed Associations. Breed associations currently provide genetic and phenotypic information to members for both bulls and cows. Breed associations are developing gateway systems which permit users access to data files. Breed associations currently have the most comprehensive data files for both production and conformation data, especially for bulls. Because many cows are not registered with the breed associations, particularly Holsteins, the proportion of cows on the breed association data files is considerably less compared to bulls. However, the population of females used most extensively for breeding stock by the AI organizations are females registered with the breed associations.

Continuous evaluations provide the breed associations with a tremendous marketing opportunity, since evaluations can change at any time. In reality, most evaluations change very little across time unless there is an influx of new data on the individual or close relatives (6). How often dairy producers request updated information from breed associations will largely depend on ease of data access and cost.

AI Organizations. The marketing departments of AI organizations currently spend a great deal of money preparing sire directories of their bulls. Because of the expense, AI organizations may be reluctant to print glossy sire directories more frequently. Continuous evaluations would require the development of alternative methods of distributing information to dairy producers. Field representatives with computers could provide up-to-date printouts of sire rankings, accessing data either from diskettes or through modem hook-ups. Low-cost newsletters could also be prepared. Updated reports could be supplements to current sire directories which highlight daughter pictures.

GENERAL DISCUSSION

Will dairy producers become confused if evaluations change continuously? Perhaps there will be an adjustment period, but I suspect that most dairy producers will readily adapt and greatly appreciate the most recent and up-to-date information available. Dairy producers make management decisions all the time based on current information. If certain feed ingredients change dramatically, dairy producers don't wait six months to change the ration. Again, if there is more current and accurate genetic information available, it makes sense that the dairy industry should utilize the updated information.

Promotion and advertising of bulls and cows in dairy publications will seem awkward at first, as the industry has become accustomed to semiannual evaluations. As an example, catalogs for sales may be outdated before the sale. But dairy producers will likely want to know the most current information available on an individual prior to purchase. Probably the biggest challenge for dairy producers would be overcoming tradition.

The industry must also determine what is equitable payment for information. Equitable payment for data is likely to become a bigger issue if evaluations are conducted more frequently. Currently, national production records are analyzed by a government agency that can not charge users for the information, whereas conformation data for Holsteins are analyzed by a non-profit corporation that can charge for information. Continuous evaluations certainly work to the benefit of the agency that can charge for information. Restructuring of responsibilities may need to occur for the collection, recording, analysis, and distribution of information

Costs associated with continuous evaluations will ultimately be paid by the dairy producer through increased semen costs, higher DHI processing fees, and/or breed association program fees. Dairy producers will need to be convinced that the economic benefits of continuous evaluations outweigh the costs. How much is the information worth? Unfortunately, assigning a value to genetic information is difficult at best. Market forces will ultimately determine value. Value of information will differ from producer to producer. Innovators will likely pay a premium for updated information that may give them a management or marketing edge over their competition. Dairy producers who do not take advantage of current information will still pay part of the cost through indirect charges. Although the potential exists to increase genetic progress by up to about 10% per year (3) with continuous evaluations, dairy producers will have to be convinced that genetic progress will be accelerated and that additional costs associated with receiving the information more frequently are justified.

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Prediction of Breeding Values for Dairy and Dual Purpose Cattle in Denmark: An Overview!

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ABSTRACT

An overview of the system for evaluating bulls and cows of Danish dairy and dual purpose cattle is given. The system is characterized by frequent evaluations of many traits and the testing of relatively many bulls. Predicted breeding values for individual traits are combined into an index for overall economic merit. Breeding values for bulls are published every other month and are also available in electronic form together with all information on all animals. Breeding values for cows are currently updated at every "test day". All data is stored in a national database, that can be accessed by all AI-societies and all extension service specialists. The Danish cattle industry is, by tradition, used to frequent evaluations and will not accept more infrequent dissemination of updated information.

INTRODUCTION

Cattle production in Denmark is mostly based on breeds that produce both milk and beef, i.e. dual purpose cattle. The main dual purpose breeds are Red Dane (RD) and Holsteins (HF), whereas Danish Jersey (DJ) basically is kept for dairy purposes only. The total number of dairy cows in Denmark is approximately 710 000. Of these, 79.7% are under official milk recording. The number of recorded cows and their average production from each breed is shown in Table 1. More than 90% of all dairy and dual purpose cows in Denmark are mated using artificial insemination (AI).

Table 1. Number of cows and average yearly production for cows in official milk recording in 1992.

	Number		Production [kg]		
Breed	n	%	Milk	Fat	Protein
Red Dane	64,750	11.4	6,776	286	236
Holsteins	368,351	65.2	7,245	302	237
Danish Jersey	83,693	14.8	5,018	313	201
others*	48,533	8.6	6,523	292	224

*Includes Danish Red and White (0.9 %) and crossbreeds.

Cattle breeding in Denmark is by old traditions organized through farmer cooperatives for milk recording and AI. Breeding goals and cooperation among AI-societies are decided in breed societies. All data recorded in Danish cattle breeding is stored in a single national database. This ensures that all information is always updated and available. Information on live animals and their direct ancestors are always online, and this information can be accessed directly by all AI-societies and all workers in the extension service, either through on-line terminals or through downloading of data.

Danish cattle breeders, for more than 15 years, have had access to almost continuous evaluation of breeding values, although the systems used have evolved over time. The running of routine computations and the preparation of publication of results etc. is the responsibility of the "National Committee on Danish Cattle Husbandry". This is a common department of the "Danish Farmers' Unions" and "Danish Family Farmers' Association".

The purpose of this paper is to give an overview of the Danish system for genetic evaluation in dairy and dual purpose cattle and to give some information on the Danish experience of running an almost continuous evaluation system.

TRAITS EVALUATED

Recording schemes in Denmark are very well developed. The most important animals to be evaluated are of course potential AI sires. In the following, the evaluation of a bull is reviewed in condensed form. Sires are evaluated using mixed model methodology for essentially all traits of interest. Results are always published as relative breeding values, i.e. the predicted value of the individuals own genes and not as in some countries as transmitting abilities, i.e. half the breeding value.

Beef Characteristics

Since most cattle in Denmark are used as dual purpose cattle, testing of a new potential AI-sire is initiated with a performance test of his own beef production characteristics. The bulls are tested on two central test stations in the period from 6 weeks and until 11 months of age. Traits recorded are average daily gain, feed intake and, longissimus dorsi area measured by ultrasonic equipment. Furthermore, disease frequency, morphological traits and a host of traits related to quality of legs and claws are recorded. Breeding values for average daily gain, muscularity and feed intake at constant weight are calculated every week using a multiple trait animal model. Breeding values are predicted for average daily gain and total feed intake in the test period and for muscularity at a fixed weight. Individual weights taken at 28 d. intervals are used as supplementary sources of information. Breeding values for individual beef production traits are combined into an overall economic index for beef production. Evaluation every week is necessary in order to decide whether a bull is to be slaughtered after the performance test or is to be moved to the AI-society that owns the bull. High veterinary costs are avoided by not moving animals with low breeding values into an AI station.

The number of bulls performance tested for beef production has in recent years been around 950 in total for all breeds. Distribution of breeds in 1992 was: RD 26.4%, HF 58.2% DJ 11.9% and others 3.5%. Bulls that are accepted after the performance test are used in 1000 to 1200 test inseminations. Not all bulls that are used in test inseminations have passed the performance test for beef characteristics, because of considerable importation of bulls from Germany, U.S.A., Canada, and New Zealand, either as live animals or as frozen semen.

As described below all animals wear a unique ear-tag. When animals are slaughtered this ear-tag is read and used for the identification of slaughter information. Information recorded on slaughtered animals includes slaughter weight, and scores for carcass conformation and degree of fatness. These records are stored in the national database, and are in the future expected to supplement beef production characteristics from the beef performance test stations. Such information cannot replace the performance test stations, because information on the bull's own performance is available before the bull is tested through test inseminations (1).

Dystocia and Stillbirth

When progeny are born they are identified with a unique ear-tag that follows the animal throughout its entire life. Dystocia, stillbirth and calf size are recorded based on scores given by the farmer or herdsman. Records on dystocia, stillbirth and calf size are used to predict breeding values for dystocia and stillbirth, both as a direct effect (trait of the calf) and as a maternal effect (trait of the dam). Calf size is used as an indicator trait only. In order to simplify selection, breeding values for dystocia and stillbirth are combined into an index for direct and an index for maternal calving difficulty. No selection on direct calving difficulty is recommended. The information is used only for selecting sires for heifer matings.

Breeding values for dystocia and stillbirth are predicted six times per year. The traits considered are dystocia, stillbirth, and calf size with records on heifers and older cows considered as different traits, i.e. a total of six traits are included in the analysis. Predictions are based on a multivariate sire-maternal grandsire model with direct and maternal effects.

Fertility

Inseminations in Denmark are almost entirely performed by AI-technicians employed by the AI-societies. Records on inseminations are used to predict breeding values for female fertility. The trait considered is 0-56 non-return rate on both nulliparous heifers and first lactation cows. Breeding values are predicted six times per year.

Milk Production

The milk production traits considered are 305 d production of milk, fat and protein. Shorter lactations or records in progress are extended and later lactations are precorrected to first lactation equivalent. Production data is extracted from the national database and evaluations are run on a dedicated computer. Data can be moved easily among computer systems such that the newest "test day" in the data extracted is only 2-3 d old. Breeding values are currently predicted using a modified sire model. The model includes all relationships among sires due to both sires and dams in the pedigree, it incorporates records on bull dams and corrects for the merit of mates. Predictions are run six times per year and the time necessary to produce the evaluations is 2-3 d. Thus, the newest "test day" in published results are about a week old.

Breeding values are computed for milk, fat and, protein production. To simplify selection these are combined into a single production index based on economic weights for each of the subtraits. The weights differ by breed but generally most of the weight is put on protein production. Within the coming year, evaluation of breeding values for milk production traits for both sires and cows will be by an animal model.

Mastitis

All milk samples in the national milk recording scheme are also measured for somatic cell count (SCC). Furthermore, in most herds all veterinary treatments are recorded on individual animals and the records are stored in the national database. Due to veterinary regulations in Denmark, farmers themselves are not allowed to do most types of medication of animals.

Prediction of breeding values for resistance to mastitis has recently been initiated based on SCC records and records of veterinary treatments of mastitis. Mastitis records are the number of treatments per cow in the period from 10 days before calving and until 180 days after calving. Breeding values are predicted using a bivariate sire model. Breeding values are published for resistance to mastitis only, and SCC-records are used as an indicator trait. In the coming years, evaluations for disease resistance are expected to be extended to other diseases as well.

Management Traits

For all bulls that are progeny tested for milk production, a random sample of 20 daughters is evaluated for linear type traits and for management traits. If the bull has promising early evaluations for production, up to 100 extra daughters are scored. A total of 19 linear morphological traits is evaluated as well as milking speed and temperament. The cows are evaluated in both first and second lactation. Not all type traits recorded have economic significance. The latter two, the management traits, are based on interviews of the herdsman. All evaluations of animals are done by professional scorers.

All 21 type and management traits are analyzed using bivariate animal models, considering scores in first and second lactation as different traits. The evaluations are run six times per year. To simplify selection, combined breeding values for general type, legs and, for udder traits are also published. These are, except for general type, based on the economic value of each subtrait included.

The heritabilities assumed in the evaluations are shown in Table 2. Since type scores in different lactations are regarded as different traits, more than 50 individual traits are included in the computations.

Table 2. Heritability assumed for each individual trait in routine evaluations of breeding values.

Trait	RD	HF	DJ
Milk yield (305 d.)	0.29	0.29	0.29
Fat yield (305 d.)	0.27	0.27	0.27
Protein yield (305 d.)	0.30	0.30	0.30
Daily Gain	0.60	0.60	0.60
Muscularity	0.40	0.45	-
Feed intake	0.30	0.30	0.30
Daughter fertility	0.03	0.03	0.03
Calving ease	0.02	0.02	0.02
Mastitis resistance	0.04	0.04	0.04
Stature	0.75	0.61	0.30
Strength	0.33	0.32	0.33
Body depth	0.28	0.15	0.32
Body bredth	0.37	0.29	0.30
Angularity	0.33	0.19	0.19
Rump width	0.37	0.27	0.44
Rump angle	0.44	0.39	0.28
Rear legs, side view	0.20	0.21	0.12
Rear legs, rear view	0.35	0.13	0.17
Hocks, general app.	0.21	0.15	0.14
Rear legs, position	0.29	0.30	0.05
Foot angle	0.20	0.21	0.18
Fore udder attachment	0.38	0.23	0.30
Rear udder width	0.50	0.29	0.28
Suspensory ligament	0.19	0.15	0.17
Udder depth	0.27	0.39	0.32
Teat length	0.43	0.19	0.33
Teat thickness	0.25	0.23	0.34
Front teat distance	0.58	0.36	0.25
Milking speed	0.30	0.24	0.29
Temperament	0.15	0.12	0.10

TOTAL MERIT

In Denmark, breeding values are usually expressed relative to a moving genetic base, the base being animals evaluated during the last 12 months. Breeding values for all traits, except milk production traits, are published as standardized values with a mean of 100 and a standard deviation of approximately 5. For milk production traits, breeding values are expressed as a percentage of the simple moving production average.

To simplify selection, the many traits are combined into a total merit index. Based on extensive economic considerations (5) each trait is given an economic weight. These weights are translated into an economic value of each unit in the breeding values for each individual trait. The weights used on each standardized subtrait is shown in Table 3. All weights except those for general type are based on the economic analysis and thus represent the marginal value of each group of traits to the profit of the dairy farmer. As can be seen, relatively large weights are put on non-production traits. The use of many traits in the evaluation of bulls and cows has been aimed at maximizing the use of available information. A proper cost-benefit analysis of expected gains versus costs of data collection and computation has never been made. The use of all information has been implemented in response to requests from the industry, that is non-technical considerations have decided the issue.

Table 3. Economic weights for each subindex in the total merit index, dependent on breed.

Trait	RD	HF	DJ
Milk production	0.55	0.50	0.60
Beef Production	0.34	0.31	0.07
Daughter fertility	0.25	0.23	0.23
Calving difficulties (maternal)	0.14	0.13	0.08
Mastitis resistance	0.19	0.18	0.19
General type	0.07	0.19	-
Legs	0.20	0.34	0.24
Udder	0.55	0.51	0.60
Milking speed	0.18	0.15	0.19
Temperament	0.03	0.03	0.06

Essentially all selection in local AI-societies is on the total merit index. Among the bulls of high ranks for total merit, however, there still is considerable variation in the breeding value for individual traits. Farmers with other breeding goals than the overall breeding goal implicit in the total merit index can, therefore, easily find bulls to satisfy their needs.

EVALUATION OF COWS

All cows are evaluated for milk production traits. The current system is based on MCC principles (2, 3). Information on own performance and information from the pedigree is combined, i.e. information from the national sire evaluation is included. Breeding values for milk production of individual cows are updated at every test day in the individual herd. Within the next year, however, this system of evaluation will be replaced by an animal model. The animal model will probably be a multivariate model considering each lactation a different trait. Research, with the goal of estimating necessary covariance matrices using multivariate animal models and REML methods, have been initiated. The evaluation will comprise all live cows as shown in Table 1. By including old cows and pedigree information, the total number of animals evaluated will be around 6.1 million. Routine evaluations will be run on a dedicated minicomputer but we have no experience with such a system yet.

About 10% of all cows are scored for linear type traits. These cows and all cows whose sire is progeny tested for type will have their own predicted breeding value for linear type traits. The prediction is again based on MCC principles. Such cows will also have a predicted breeding value for total merit, computed on the same principles as for males.

Danish dairy and dual purpose cattle breeding have for many years tested relatively many new young bulls every year. Table 4 shows the number of new bulls that had breeding values published in 1992. The HF breed, for example, had 439 bulls performance tested for beef characteristics and 344 new bulls were evaluated for milk production. In order to test this many bulls approx. 30% of the cow population is inseminated with semen from test sires.

Table 4. Number of young bulls evaluated in 1992 for different traits.*

	Breed		
Trait	RD	HF	DJ
Performance test, beef	212	439	129
Progeny test			
Milk production	84	344	98
Dystocia & Stillbirth	84	344	98
Fertility	84	344	98
Mastitis resistance	62	224	64
Type traits	49	290	59
Total Merit	49	290	59

* Only bulls owned by AI-organizations.

PUBLICATION OF RESULTS

Results are published in several ways. For beef characteristics, evaluations are run every week using a multiple trait animal model. Results for bulls are mailed directly to the owner of the bull, when the bull is 10 months old and at the end of the test. Results are also published in a booklet once a year. For all other traits evaluations are run every other month. Results are published in condensed tables in a booklet of 100-120 pages and mailed to all subscribers. Once a year all results of the past year are published in similar form (4).

Evaluations of bulls are not printed before they reach a minimum reliability of 60%. Only results on young bulls are published in the bimonthly publications but in the year-end reports results on all bulls with semen available are published. A bull is regarded as a young bull as long as daughters from the test inseminations are included in the evaluations with extended records.

The most important information, however, is in electronic form. All new breeding values are updated in the national database and are always available here earlier than the printed version. Breeding values of all animals are updated in the database irregardless of their reliability. All AI-societies and everybody working in the extension service can access the database through on-line equipment and they can download whatever fields they chose to select.

Downloading is the most common form when making local catalogs of available germ plasm. Individual AI-societies can download information in a variety of formats. The most common form is "camera ready" postscript files that include graphical representations of breeding values of individual bulls. Also breeding values are automatically updated on all output that farmers request simultaneously with normal milk recording.

Currently breeding values of cows are predicted simultaneously with the processing of monthly test day records using an approximate procedure (2). In the near future all evaluations will be by an animal model that will be run six times per year. By then printed breeding values will not be as current as those in the system now in place, but will instead have better statistical properties. The time needed to run a bimonthly animal model evaluation is expected to be the same as for the current sire model so that the newest "test day" in published results will be less than a week old.

When downloading, individual farmers can access their own data only plus public information on bulls. As a standard, a farmer can download all data on all active cows in his herd. He can further chose to include data on culled animals and on heifers and bull calves. Furthermore, he can chose to download information on AI bulls available through his local AI-society. The most important use of downloaded data is for production control in stead of planning matings. Extension specialists can access data on all farms in their area.

The system used for downloading is based on an electronic mailbox system. In the mailbox, messages or data to the central database can be placed as well as requests for data from the national database. Requests are processed every 15 minutes. The system is still quite new and is used by 10% of all herds, such that at the moment there are less than 100 herds that are downloading on any given day.

INDUSTRY ACCEPTANCE OF FREQUENT EVALUATIONS

The operation of AI-societies throughout Denmark relies on fast access to updated information. That is, cost of storing bulls, semen etc. is minimized by not keeping inferior animals or genetic material. Frequent evaluations make it possible to keep the generation interval short. Smith and Burnside (6) estimated a reduction in generation intervals of 10-15% using the Danish system of more frequent evaluations compared to biannual evaluations. Such a reduction will increase genetic gains by similar amounts.

A disadvantage of very frequent evaluations is that information on bulls and cows changes very often, leading to some confusion among farmers as well as some extension specialists. However, due to the long tradition of semi-continuous evaluations in Denmark, discussion on this topic never really has been an issue. On the other hand a recent suggestion on reducing the number of yearly evaluations was abandoned due to broad resistance from the industry. Therefore, frequent evaluations are required by the industry but precise cost-benefit analysis of frequent versus infrequent evaluations have never been made under the Danish conditions.

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