

## A Method for Combining United States and Canadian Bull Evaluations

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### ABSTRACT

Canadian and US genetic evaluations for July 1991 were combined for 3304 Holstein bulls evaluated in Canada that had US progeny or a cross-reference code. Canadian evaluations of the bulls and their sires and dams were converted to US PTA. Combined PTA were weighted averages of progeny information from both countries and parent average. Parent average was recomputed from the sire's combined evaluation and the dam's evaluation with the most daughter equivalents. Bulls were processed in birth year order so that combined evaluation of sire was available. Progeny contribution was adjusted to remove the influence of the bull's evaluation on progeny evaluations through their parent averages, which left only the portion that was due to progeny records and grandprogeny information. A weighted average of adjusted progeny contributions was combined with parent average to form a combined PTA more accurately than possible by averaging domestic and converted PTA. Combined reliability was computed by summing daughter equivalents from progeny and from updated evaluations of parents. Canadian daughter equivalents were multiplied by .9 to approximate US values. Combined evaluations simplify bull selection by providing comparable and complete information for bulls evaluated in two countries.

(Key words: animal model, genetic evaluation, combined evaluation, conversion)

Abbreviation key: DE = daughter equivalent; MFP\$ = genetic-economic index based on

PTA milk, fat, and protein; PA = parent average; PC = progeny contribution.

### INTRODUCTION

A global market exists for genetic products, including semen, embryos, and cattle. Trade involving the US and Canada is a major part of that market. For buyers to make informed decisions, they must be able to rank competing animals on the same scale. Considerable effort has been expended in development of conversion formulas (4, 6) so that the evaluations from one country can be expressed on the scale of another.

Because of the degree of germplasm exchange between the US and Canada, many bulls have progeny in both countries. Currently, the US evaluation system ignores daughter information from Canada, thereby decreasing potential accuracy of evaluations. This problem is most acute for bulls evaluated in Canada that have a few daughters in the US. These bulls may have an unrepresentative evaluation in the US because of few daughters or importation of only selected daughters. In addition, their parent averages (PA) likely are based in part on unknown-parent group solutions (7) because a Canadian dam is unlikely to have a US evaluation.

Several strategies might produce more accurate comparisons of Canadian and US bulls. Data from both countries could be processed in a single evaluation. Evaluations from combined data have been computed for Ayrshire and Jersey breeds in both countries as a research project (2, 8, 9), but replacement of separate national evaluations with an international evaluation will require much additional cooperation and coordination. Several studies (1, 2, 10) relied on a method of Schaeffer (11) to combine bull evaluations from two or more countries. This approach accounts for scale differences with factors derived from variances of evaluations and estimates country differences simultaneously with bull rankings.

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A third alternative is to include information from another country's evaluation as an extension of the domestic data set. Information could be added to equations before iteration, or evaluations could be combined after national evaluations were completed. Combined statistics could include number of daughters, average yield, daughter yield deviation, and reliability as well as final evaluations for animals in both countries. Presentation of the same information for combined evaluations as for domestic ones would simplify their use. Augmentation of equations before iteration allows information to affect domestic evaluations of all cows and bulls; however, information from the other country must be available early in the evaluation process, and all solutions are dependent on the conversion formulas. If evaluations are combined after processing, data from other countries do not need to be available until processing is completed, and conversion formulas can be developed using national evaluations.

The purpose of this study was to develop a system for combining Canadian and US evaluations for milk, fat, and protein yields and to develop an appropriate measure of reliability. This goal included determining what information from the Canadian evaluation system was required and how the combined evaluations should be integrated into the US evaluation system.

#### MATERIALS AND METHODS

July 1991 Canadian evaluations for 5124 Holstein bulls and 3658 bull-dams were obtained from Agriculture Canada. For bulls, diagonals of bull equations, number of evaluated parents, and progeny contribution (PC) to bull evaluation were provided in addition to evaluation information routinely distributed. Of these Canadian bulls, 3304 also were included in the US evaluation system. About 13% of these bulls were included because they had been assigned National Association of Animal Breeders cross-reference codes even though they did not have US daughter information. Canadian evaluations and PC were converted from breed class average (BCA) points to US PTA in kilograms with official US conversion formulas for July 1991:

$$PTA_{\text{milk}} = -215 + 60(BCA_{\text{milk}});$$

$$\begin{aligned} PTA_{\text{fat}} &= -4.7 + 2.016(BCA_{\text{fat}}); \\ PTA_{\text{protein}} &= -5.3 + 1.832(BCA_{\text{protein}}). \end{aligned}$$

For each bull, PA and PC were determined. For US evaluations, PA and diagonal components were saved. The weights  $w_1$  and  $w_3$  in the PTA formula (12)

$$PTA = w_1PA + w_3PC,$$

were reformulated to

$$\begin{aligned} w_1 &= v_1/(v_1 + v_3); \\ w_3 &= v_3/(v_1 + v_3), \end{aligned}$$

where  $v_1 = 2, 4/3,$  or  $1$  (depending, respectively, on whether both, one, or neither of the bull's parents were evaluated), and  $v_3$  is contribution of progeny to the diagonal, which is  $.5\sum d$  (summation over progeny;  $d = 1$  if mate was evaluated or  $.67$  otherwise). Then, PC was computed as

$$PC = [(v_1 + v_3)PTA - v_1PA]/v_3.$$

VanRaden and Wiggans (12) derived daughter yield deviation to provide an indication of a bull's daughter performance that is nearly independent of information from other relatives. That derivation indicated that PC has a sizable contribution from the bull himself through PA of progeny. In combining PC across countries, a bull's evaluation is expected to change; therefore, it should be removed from PC before combination. Contribution of PA to PTA of each progeny is  $w_1$  of the progeny. However, this information is not collected routinely for bulls.

Accuracy of a bull's evaluation can be expressed in daughter equivalents (DE) (12), and DE were computed from US reliabilities and Canadian repeatabilities:

$$DE = [(4 - 2h^2)/h^2](R)/(1 - R),$$

where  $R$  is the national measure of accuracy. The Canadian heritability of  $.33$  (Robinson, 1991, personal communication) was used to calculate DE from Canadian repeatability. Because the Canadian method overestimates repeatabilities (5), Canadian DE were reduced by multiplication by  $.9$ . This adjustment made them comparable with US DE as determined

from comparison of results from both US and Canadian systems applied to the same data (8, 10). To estimate DE from progeny, DE from PA ( $DE_{PA}$ ) can be subtracted from total DE. This is a slight underestimation because  $DE_{PA}$  includes the bull's own contribution. Although the bull's contribution to PA could be removed (12), its impact is minimal and, therefore, was not removed for combining evaluations. Then, DE for a combined evaluation ( $DE_{combined}$ ) was the sum of  $DE - DE_{PA}$  from Canada,  $DE - DE_{PA}$  from the US, and  $DE_{PA}$  from the combined evaluation. Reliability for combined evaluations was

$$\frac{DE_{combined}}{DE_{combined} + (4 - 2h^2)/h^2}$$

where the US heritability of .25 (13) was used.

The fraction of PC from the bull's own evaluation ( $f$ ) is the weighted average of PA weights of the progeny

$$f = \Sigma(dw_{1_{progeny}})/\Sigma d.$$

The formula for  $f$  was derived by expanding PC to  $2PTA_{progeny} - PTA_{mate}$  (12, 13) and then expanding  $PTA_{progeny}$  to PA, yield deviation, and progeny contributions. Because  $w_{1_{progeny}}$  for individual progeny were not available,  $f$  was estimated ( $\hat{f}$ ) using the relation between number of progeny and DE from progeny as  $v_3/[v_3 + (5/36)DE_a]$  where  $DE_a$  is total DE with limitation for daughters in a single herd removed for the herd with the most daughters (see Appendix). Then PC adjusted for the bull's contribution (APC) is

$$APC = [PC - \hat{f}(PTA_{bull})]/(1 - \hat{f}).$$

Solving for PC and substituting into the PTA formula,

$$PTA_{bull} = \frac{v_1 PA + (1 - \hat{f})v_3 APC}{v_1 + (1 - \hat{f})v_3}$$

The combined evaluation ( $PTA_{combined}$ ) was computed from PA and US and Canadian (Can) APC as

$$PTA_{combined} = \frac{v_1 PA + (1 - \hat{f}_{US})v_3 APC_{US} + (1 - \hat{f}_{Canada})v_3 APC_{Canada}}{v_1 + (1 - \hat{f}_{US})v_3 + (1 - \hat{f}_{Canada})v_3}$$

where PA was computed using the combined evaluation of the bull's sire and the dam's evaluation with the greatest DE. For 31% of dams, the US evaluation was selected. For sires without a combined evaluation, the US or converted Canadian evaluation was used. Bulls were processed in birth year order; therefore, combined evaluation of a bull's sire was available when a bull was processed.

To provide supplemental information, mean yields were calculated weighted by number of daughters. Evaluations for component percentages were computed as in the US system. Bulls were ranked according to the 1991 USDA-DHIA genetic-economic index based on PTA (in kilograms) for milk, fat, and protein (MFP\$):

$$\begin{aligned} MFP\$ = & (\$.0967/\text{kg})PTA_{milk} \\ & + (\$.260/\text{kg})PTA_{fat} \\ & + (\$.302/\text{kg})PTA_{protein}. \end{aligned}$$

Percentile was determined from thresholds for July 1991 USDA-DHIA evaluations based on MFP\$ for active AI bulls in the US.

## RESULTS

For the 729 bulls born in 1977 or later (a period likely to include all bulls of current interest), 47% had no US evaluation released (Table 1). These bulls had either 1 to 9 US daughters, which is less than the 10 required for evaluation release (3), or no daughters and a National Association of Animal Breeders cross-reference code. Mean reliability for combined evaluations of these bulls is less than reliability for Canadian evaluations because a heritability of .25 was used in the combined evaluation. For the 19% of bulls that had 10 to 30 US daughters, mean reliability increased from 59% for US evaluation to 91% for the combined evaluation. Evaluations for these bulls were improved by addition of information from Canadian daughters. For bulls with more than 30 US daughters, mean reliability was high for US evaluation (91%) before the addition of the Canadian information; however, reliability still increased to 97% with the combined evaluation.

TABLE 1. Numbers of bulls, mean numbers of daughters, and mean bull reliabilities for bulls born in 1977 or later that were evaluated in Canada and included in US system by daughter country and number of US daughters.

Number of US daughters	Number of bulls	Mean number of daughters			Mean reliability		
		US	Canada	All	US	Canada	Combined
0 to 9 <sup>1</sup>	341	3	150	153	...	91	88
10 to 30	141	18	307	325	59	93	91
>30	247	2246	1150	3396	91	92	97
All	729	766	519	1285	79	92	92

<sup>1</sup>Evaluation from US not released.

The similarity between the Canadian and combined evaluations for bulls with fewer than 10 US daughters is shown in Table 2. For those bulls, the only differences between the two evaluations are that PA has been updated and a few US daughters included, which are reflected in the correlation of .999. For bulls with 10 to 30 US daughters, correlation between US and combined evaluations was only .837 because Canadian evaluations supply most of the information. For evaluations with greater than 30 US daughters, US evaluations supply somewhat more information than Canadian evaluations, but both are highly correlated with combined evaluations.

Mean reliabilities and MFP\$ for some of the top 40 bulls for MFP\$ based on combined evaluations are in Table 3. Table 3 includes only bulls with Canadian evaluations that also were included in the US evaluation system. Half of these bulls did not have a released US evaluation. These bulls provide examples of characteristics of the combination process. The slight change in the MFP\$ of the top bull resulted from the change in PA. The combined evaluation MFP\$ for the third bull was the same as his US MFP\$ even though his Canadian MFP\$ was higher because less than 1% of his daughters were in Canada. For the seventh bull, the higher Canadian MFP\$ for the seventh bull did raise his combined evaluation MFP\$ over his US MFP\$. The ninth bull had a combined evaluation MFP\$ that was slightly higher than either his US or Canadian MFP\$, which could result either from a change in PA or a greater weight on daughter information in the PTA formula. The top 10 bulls ranged in percentile from 87 to 99.

## DISCUSSION

The method developed for combining US and Canadian evaluations 1) approximates animal model solutions, 2) removes bull contribution to his progeny before combination, which is important for bulls with substantial differences between US and Canadian evaluations, and 3) provides a measure of accuracy comparable with US reliability. For many bulls, the combined evaluation is essentially the same as a converted evaluation; however, the combination method enables full use of information from both countries with relatively few computational requirements. This combination method is an improvement over national evaluations augmented by converted evaluations because 1) no bull would have two evaluations (e.g., a US evaluation possibly based on few daughters and a converted Canadian evaluation) and 2) Canadian parentage would be more accurately represented. Currently, the US evaluation may include little information on Canadian parents, especially dams.

In the Canadian system, a bull with US parents has his parent contribution computed

TABLE 2. Correlations between national and combined US-Canadian milk evaluations by number of US daughters.

Number of US daughters	Evaluations	
	US	Canadian
0 to 9 <sup>1</sup>	...	.999
10 to 30	.837	.994
>30	.983	.958

<sup>1</sup>Evaluation from US not released.

TABLE 3. Numbers of daughters; reliabilities; economic indexes based on PTA for milk, fat, and protein<sup>1</sup> (MFP\$); and percentile rankings for some of top 40 bulls for MFP\$ from combined US-Canadian evaluation.

Bull rank	Birth year	Number of daughters			Reliability			MFP\$			Percentile
		US	Canada	All	US	Canada	Combined	US	Canada	Combined	
				————— (%) —————			————— (\$) —————				
1 <sup>2</sup>	1985	0	77	77	...	91	87	...	339	338	99
2 <sup>2</sup>	1985	3	36	39	...	78	74	...	284	284	98
3	1981	5085	43	5128	99	80	99	272	313	272	97
4 <sup>2</sup>	1987	0	14	14	...	66	61	...	288	268	96
5	1981	1123	166	1289	98	94	98	259	260	260	95
6 <sup>2</sup>	1985	0	73	73	...	88	85	...	274	259	95
7	1978	26,225	703	26,928	99	99	99	246	315	250	92
8 <sup>2</sup>	1985	1	75	76	...	88	84	...	260	247	92
9	1984	410	23	433	96	73	96	236	205	237	87
10	1982	5793	54	5847	99	84	99	236	231	236	87
20	1985	0	97	97	...	92	88	...	200	197	62
30	1986	0	106	106	...	92	89	...	190	186	55
40	1984	10	77	87	55	89	86	204	161	172	44

<sup>1</sup>MFP\$ = (\$.0967/kg)PTA<sub>milk</sub> + (\$.260/kg)PTA<sub>fat</sub> + (\$.302/kg)PTA<sub>protein</sub>.

<sup>2</sup>Evaluation from US not released because information from at least 10 US daughters was not available.

including his parents' previous US evaluations if the reliability of the US evaluation is sufficiently high. Because Canadian evaluations are separated into parent contributions and PC, more current US evaluations are used in the parent contribution. After combining evaluations, PA for progeny-tested bulls could be updated with combined sire evaluations to provide a more accurate estimate of bulls' merit.

Because evaluations rather than lactation data are combined and the procedure is not iterative, some inconsistencies will exist in information released to the dairy industry. For example, cow evaluations will be computed from the sire's national rather than combined evaluation; therefore, the PA used in her evaluation can not be computed from the reported evaluations. For progeny with only US evaluations, PA could be updated as in the Canadian system. This extended use of combined evaluations probably does not add sufficient accuracy to warrant additional computer processing. The most practical way to affect all solutions would be to include evaluations before iteration or to combine lactation records.

Simultaneous release of evaluations in the US and Canada makes incorporation of the most current evaluations impractical. Results from the previous evaluation must be used. Bulls with fewer than 10 US daughters and marketed in the US will have release of their

combined evaluation delayed to allow inclusion of current Canadian evaluations.

This research was motivated by US and Canadian industry representatives meeting to develop international marketing guidelines. Applying the practice of developing conversion formulas to computing converted evaluations for bulls of interest seems to reduce effectively the confusion about the merit of imported semen. Once the commitment to provide evaluations for Canadian bulls had been made, the objective was to develop a method that provided the most accurate evaluations within time and computing constraints. Providing information for bulls evaluated in both the US and Canada in comparable form should simplify sire selection and make the US market more accessible to the top Canadian bulls. Because evaluations are combined, joint sampling of bulls in the US and Canada is more attractive.

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APPENDIX

The limitation on DE from a single herd (12, 13), because of inclusion of a herd x sire

interaction effect in the model, complicates the relation between number of progeny and DE from progeny. Effect of limitation on DE was estimated based on the number of daughters in the herd with the most daughters (n), which had the greatest impact on limiting DE. Total number of progeny is estimated as 2v<sub>3</sub> because mates are assumed to be known (d = 1). Ratio (p) of daughters in the herd with most daughters to total progeny was computed: p = n/2v<sub>3</sub>. That fraction of total DE was expanded by the ratio of n to DE from the herd with most daughters [1/(.16 + .84/n)] (12) and the increase added to DE:

$$\begin{aligned}
 DE_a &= p(DE)\{n/[1/(.16 + .84/n)]\} \\
 &\quad - p(DE) + DE \\
 &= p(DE)[(.16n + .84) - 1] + DE \\
 &= [p(.16n - .16) + 1](DE)
 \end{aligned}$$

where DE<sub>a</sub> is total DE with limitation for daughters in a single herd removed for the herd with the most daughters.

Because w<sub>1<sub>progeny</sub></sub> for individual progeny were not available, each progeny was assumed to have the same weight for PA. Therefore, the numerator (v<sub>1<sub>progeny</sub></sub>) and denominator

$$(v_{1_{progeny}} + v_{2_{progeny}} + v_{3_{progeny}})$$

for w<sub>1<sub>progeny</sub></sub> (12) could be summed across progeny. Then, Σv<sub>1<sub>progeny</sub></sub> = 2Σd = 4v<sub>3</sub>, and (5/9)DE<sub>a</sub> estimates Σv<sub>2<sub>progeny</sub></sub> + Σv<sub>3<sub>progeny</sub></sub>, where 5/9 is the inverse of the error to genetic variance ratio based on a heritability of .25 and a repeatability of .55 (13). The estimate of f (f-hat) was calculated as

$$\begin{aligned}
 \hat{f} &= \Sigma v_{1_{progeny}} / (\Sigma v_{1_{progeny}} + \Sigma v_{2_{progeny}} \\
 &\quad + \Sigma v_{3_{progeny}}) \\
 &= 4v_3 / [4v_3 + (5/9)DE_a] \\
 &= v_3 / [v_3 + (5/36)DE_a].
 \end{aligned}$$