Examination of International Genetic Evaluations of Holstein Bulls

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ABSTRACT

The first large-scale, international genetic evaluation of Holstein bulls computed by the International Bull Evaluation Service Centre in February 1995 was examined and compared with national evaluations from Canada, Denmark, Finland, France, Germany, Italy, Sweden, The Netherlands, and the US. Assumption of a genetic correlation of 0.995 between all countries and exclusion of bull daughters from a country in which the bull had not been sampled resulted in correlations of essentially unity between national and international evaluations. For the few bulls sampled in multiple countries, correlations were lower but still high (≤ 0.95). Genetic trend was more rapid for countries in which genetic merit for earlier years was lowest. Differences among countries in genetic merit of recent bulls have decreased markedly, especially between the US and other countries. Mean evaluation for bulls born during 1988 in the US surpassed means for bulls in France, Italy, and The Netherlands by <3 kg for PTA for protein. Application of seven national economic indexes showed that some indexes with different mathematical forms can rank bulls similarly. If the official index for one country is assumed to be optimal, use of an index from another country could substantially reduce the mean merit of selected bulls by more than one-half an index standard deviation. Selection on either national or international genetic evaluations can give rapid genetic progress if the economic index is correct.
(**Key words**: breeding, genetics, international evaluation)

Abbreviation key: **INTERBULL** = International Bull Evaluation Service.

INTRODUCTION

Countries can differ in language, currency, and method for expression of genetic merit of dairy animals. Even if a country chooses to use the same terms for genetic merit as another country (e.g., dollars, francs, breeding values, transmitting abilities, pounds, or kilograms), evaluations are not directly comparable. Trait definitions, bases, models, and environmental conditions differ. Dairy genetics, especially in the form of semen or embryo, can be transported more easily than the technology to assist customers. Breeders need to know whether they should purchase genetic material from another country or, more precisely, how those animals would rank locally. When a group of bulls is used in two countries, prediction (or conversion) equations can be developed for application to bulls used in only one of the countries. Least squares regression was an obvious early choice but gave way to the Goddard (2) and Wilmink (11) methods that consider the accuracy of the evaluation in the importing country. These methods have been described and compared by Powell et al. (6).

Guidelines (3) for the minimum amount of information needed for use of the Goddard (2) and Wilmink methods (11) were developed by **INTERBULL** (International Bull Evaluation Service). If those minimums were not met, use of a theoretical method was suggested. That method used a scaling or regression factor that was the ratio of population standard deviations for evaluations from the two countries. Because France does not consider its evaluations of foreign Holstein bulls with daughters in France to be accurate, French researchers developed a method (4, 5) that used evaluations of full brothers in two countries to determine the base difference and used ratios of population standard deviations for the scaling factor.

Schaeffer (7) suggested a linear model combination of evaluation and pedigree data from many countries simultaneously that produced combined evaluations as well as conversion equations as a by-product. To allow application of the linear model, progeny data from all countries were adjusted to a common scale before the data were combined; the male relationships connected the data. This procedure was a significant advance toward obtaining a single global ranking for each trait. However, recognition that the genetic correlation between countries is not likely to be unity

Received January 8, 1996.
Accepted April 22, 1996.

suggested that a single ranking for all locations is not appropriate. Schaeffer developed an evaluation method that considers performance in different countries as different but correlated traits (8) and uses daughter yield deviations (10) as the measure of daughter performance.

The INTERBULL Centre (Uppsala, Sweden) applied a modification of the procedure of Schaeffer (8) to Nordic Holstein and Ayrshire bull data in August 1994 for their first routine release of genetic evaluations. A varying genetic correlation was not employed, deregressed evaluations rather than daughter yield deviations were used, and evaluations for a bull in a country that used the bull after first evaluation in another country were not considered. All genetic correlations were assumed to be 0.995 for test evaluations in December 1994 and for the first large-scale, routine release of evaluations that included data from 10 countries and five breeds in February 1995 (1).

The objective of this study was to examine the results of the February 1995 INTERBULL evaluation for Holsteins to determine 1) relationships between national and international evaluations for bulls with data from only one country compared with bulls that had daughter evaluation data from multiple countries, 2) genetic merit and trends in each population, and 3) relationships between rankings of bulls and the impact on sire selection for various national economic indexes applied to the international evaluations.

MATERIALS AND METHODS

February 1995 INTERBULL evaluations for milk, fat, and protein were available for 54,781 Holstein bulls (Table 1). Evaluations were expressed on the scales of each of nine countries: Canada, Denmark, Finland, France, Germany, Italy, Sweden, The Netherlands, and the US. Some older bulls from some countries did not have protein evaluations, and bulls from Finland did not have fat evaluations. Canadian data supplied to INTERBULL for international evaluations were from national evaluations based on only first lactations and, therefore, were not official Canadian evaluations. All national evaluations of bulls included herds in at least 10 herds, and all bulls were required to have been coded as having been sampled randomly in an AI program. Countries with bull evaluations considered as unofficial in that country probably did not submit those data to the INTERBULL Centre even though the requirement for number of herds may have been met. The country with the most daughters of a bull was designated as the country of that bull. Most bulls had daughter contributions from only one country; however, a few were used as young bulls in more than one country, and all daughters from these countries contributed. There were 913 bulls with daughter contributions from two countries, 49 from three, and 1 from four. Each country provided pedigree data, including the original identification number for bulls that had been reidentified later in other countries, if available.

TABLE 1. Numbers of Holstein bulls and mean birth date by country with the most daughters of a bull.

Country	Bulls	Birth date
	(no.)	$\bar{X}$
US	19,224	October 1979
France	9546	October 1979
Germany	7304	March 1981
The Netherlands	5575	December 1981
Canada	5440	August 1979
Denmark	2907	July 1985
Italy	2188	June 1981
Sweden	1921	March 1977
Finland	676	January 1981

Daughter yield deviations were neither available from nor calculated uniformly by all countries. Thus, deregressed evaluations were used for the daughter contribution (9). Deregression uses only male relationships traced through sires and maternal grandsires. The merit of a dam is assumed to equal the mean of the merit for the maternal grandsires and the appropriate group of maternal granddams. The Mendelian sampling for the dam and the difference of the granddam from the group are not part of the ancestor merit but instead are included in the apparent daughter merit. Because of this method for including dam merit, multiple-country evaluations (8) with only male relationships are similar to national evaluations from an animal model, especially for bulls with minimal data from other countries. Sire variances were computed as the geometric means of the product within year of variance of deregressed evaluations and normal evaluations.

Correlations between national and international evaluations for milk yield were computed for bulls from France, Germany, Italy, The Netherlands, and the US. Correlations were computed separately for bulls with data from only one country and those with data from more than one country. Not all bulls could have international evaluations matched with national evaluations, probably because of different identification numbers in the two data files or the occurrence of international evaluations for bulls that did not meet national requirements for general distribution. Difficulties in linking animal identification from

TABLE 2. Weights applied to yield traits for national economic indexes of seven countries.

Country	Yield			Protein percentage
	Milk	Fat	Protein	
Canada	. . .	3.00	8.000	. . .
Denmark	–0.00400	0.28	0.724	. . .
France	. . .	. . .	2.300	34.5
Germany	. . .	0.15	0.600	. . .
Italy	–0.77800	4.50	50.800	. . .
The Netherlands	–0.15000	2.00	12.000	. . .
US	0.05466	0.58	1.470	. . .

different countries are considerable, and reidentification of animals is strongly discouraged. However, the need for crossreference systems will remain for many years.

Correlations were computed between international evaluations for milk and protein yields, expressed on the scales of different countries. Because genetic correlations assumed by INTERBULL for all country pairs were near unity (0.995), correlations of evaluations relative to the scales of different countries were expected to be high. Genetic trend can exaggerate correlations calculated from data that include many years; therefore, these correlations were between residuals after fitting birth year. Birth years were not always available, and some early dates were suspect. After birth years were restricted to 1950 through 1990, international evaluations were available for 54,153 bulls for milk yield and 49,637 bulls for protein yield.

Genetic means for bulls with evaluations provided to the INTERBULL Centre were determined by birth year and country. Milk and protein means indicated relative merit, and changes over time indicated rate of progress. Means were expressed on the US scale to simplify interpretation of results.

Economic indexes used in Canada, Denmark, France, Germany, Italy, The Netherlands, and the US for combining yield traits (Table 2) were applied to international evaluations on the US scale, and correlations were computed for residuals after birth year was fitted to remove effect of genetic trend. Bulls were required to have evaluations for milk, fat, and protein yields and to have birth years from 1950 through 1990; data were available for 48,962 bulls.

The impact of selection based on the various indexes was examined by determining the difference in the mean index for bulls selected on the official index of a country versus indexes from other countries and by expressing that difference in standard deviation units. All indexes were applied to evaluations only on a US scale because comparison of index impact (rather than differences in evaluations across countries) was of interest. For the 14,277 bulls born during 1986 or later, mean indexes were computed for the top 100 bulls for each of the 7 country indexes (Table 2). The difference between the mean indexes for country A of the top 100 bulls for the index of country A and of the top 100 bulls for the index of country B was divided by the standard deviation of index for all bulls of country A:

$$(\bar{A}_{\text{top } 100_{\text{index A}}} - \bar{A}_{\text{top } 100_{\text{index B}}})/SD_{\text{all bulls}_{\text{index A}}}.$$

This procedure produced a measure of loss in standard deviation units from selection on another index.

RESULTS

For over one-third of the bulls evaluated by INTERBULL, the US was the country that had the most daughters of that bull (Table 1). Although some bulls were born as recently as 1990, mean birth date was about a decade earlier. Countries differed in recentness of birth dates, which reflected differences in national programs for sire sampling (age of bulls at semen collection, age of daughters at calving, and time required for analysis of lactation data) and in release dates for national evaluations. For bulls sampled in 1989, data for all bulls were included by Italy, The Netherlands, and the US, and data for most bulls were included by Canada, Denmark, and Germany; however, data for less than one-half of those bulls were included for Finland, France, and Sweden.

National and international evaluations were almost perfectly correlated (≥0.9995) for bulls with evaluations based on daughters from only one country (Table 3). For bulls sampled in more than one country, correlations were lower (0.9481 to 0.9976) although still high (≥0.98), except for France. These correlations would be expected to increase when lower genetic correlations are used for future international evaluations. Most of the bulls among the 47 with most of their daughters in France but with daughters also included from other countries were bulls simultaneously sampled in the US. Although the majority

TABLE 3. Numbers of Holstein bulls sampled in single and multiple countries, mean percentages of total daughters from the country with the most daughters for bulls sampled in multiple countries, and correlations between national and international evaluations.

Country with most bull daughters	Bulls sampled		Daughters from country with most daughters for bulls sampled in multiple countries	Correlation between national and international evaluations	
	Single country	Multiple countries		Bulls sampled in single country	Bulls sampled in multiple countries
	(no.)		(%)		
France	6786	47	63	0.9998	0.9481
Germany	6686	125	79	0.9989	0.9875
Italy	2119	16	75	0.9995	0.9866
The Netherlands	4998	69	67	0.9998	0.9910
US	18,668	490	90	0.9998	0.9976

(63%) of daughters were in France, a considerable number were in the US. However, a lower correlation between national and international evaluations was not always associated with a lower percentage of daughters from the country with the most daughters as shown by data for The Netherlands as the country with most daughters.

Correlations between international evaluations, expressed on the scales of the various countries, are in Table 4 for milk and protein. These correlations were computed from the residuals after fitting birth year, which was appropriate, because the correlations between birth year and yield evaluations were about 0.7. As expected from the high genetic correlations assumed between countries (0.995), correlations also were high between international evaluations expressed on different scales; the only correlations of <0.997 involved evaluations on the US scale. Although those correlations are still high, why they would be lower than correlations between evaluations from other countries was not apparent. The US bulls had large populations for bulls sampled in a single country (18,688) or in multiple countries (490) and were the most important source of pedigree information for determining connections between animals; however, neither of these factors would seem to explain the lower correlations.

Mean evaluations on the US scale are in Table 5 for milk yield and Table 6 for protein yield for even birth years from 1976 through 1988. Because the country designations refer to the country with the most daughters of a bull, these means are an assessment of the genetic merit of domestic bulls and do not consider improvement from the use of foreign semen except for the sire-son-grandson pathway. Data from Denmark were limited through 1980. Italy expanded its progeny-testing programs considerably during the middle 1980s, and numbers of bulls for the early years were fewer. Finnish data were limited for all years. However, the means generally were consistent, even when based on fewer numbers. Not surprisingly, mean annual increases tended to be higher for countries with lower means in early years and vice versa. Means were highest for the US for all years, but the difference has diminished considerably for many countries. Although a high mean is desirable, breed-

TABLE 4. Correlations between international evaluations[1] of Holstein bulls for milk yield (above diagonal) and protein yield (below diagonal) expressed on scales of different countries.

Country	Canada	Denmark	Finland	France	Germany	Italy	Sweden	The Netherlands	US
Canada		0.997	0.997	0.998	0.998	0.998	0.997	0.997	0.984
Denmark	0.999		0.999	0.999	0.998	0.998	0.998	0.998	0.993
Finland	0.999	0.999		0.999	0.999	0.999	0.999	0.999	0.993
France	0.999	0.999	0.999		0.999	0.999	0.999	0.999	0.990
Germany	0.998	0.998	0.999	0.999		0.998	0.998	0.997	0.988
Italy	0.998	0.999	0.999	0.999	0.997		0.999	0.999	0.989
Sweden	0.999	0.999	0.999	0.999	0.999	0.999		0.999	0.992
The Netherlands	0.999	0.999	0.999	0.999	0.998	0.999	0.999		0.993
US	0.992	0.996	0.996	0.993	0.991	0.996	0.996	0.993	

[1]Effects of birth year removed.

TABLE 5. Mean international evaluations of Holstein bulls for milk yield on the US scale (PTA) by country with the most daughters of a bull and birth year and mean annual increases in evaluations.

Birth year	Canada	Denmark	Finland	France	Germany	Italy	Sweden	The Netherlands	US
	(kg)								
1976	−708	−827	−971	−810	−811	−719	−1007	−1012	−424
1978	−698	−808	−610	−629	−730	−710	−916	−950	−357
1980	−563	−630	−544	−636	−642	−504	−947	−799	−237
1982	−409	−687	−500	−403	−588	−365	−793	−649	−80
1984	−335	−536	−498	−361	−542	−403	−739	−544	20
1986	−170	−365	−372	−146	−406	−57	−645	−359	131
1988	−159	−168	−178	76	−226	106	−288	−25	224
Mean annual increase	46	55	66	74	49	69	60	82	54

ers have virtually no interest in average animals; animals of extremely high genetic merit command attention. Therefore, variation is also important, and countries with larger sampling programs and more accurate progeny tests have an advantage in identification of outstanding animals.

The US was recognized as a source of top genetics long before comparisons of genetic sources (e.g., Tables 5 and 6) became available. Older sires from the US provide the ties that make international evaluations more widely accepted across countries. For bulls born during 1988, 96 of the top 100 bulls for international evaluations for protein yield expressed on the US scale (≥94 on other scales) were sired by US bulls. Even after bulls with US daughters were excluded, 96 of the top 100 bulls for protein yield still had US sires. Of the top 100 domestic bulls for protein in each country, 75 to 99 bulls had US sires, except for Finland, for which only 39 of the top 100 bulls had US sires. Use of US genetics has allowed other countries to improve the genetic merit of their sampled bulls, and the mean merit for new bulls in France, Italy, and The Netherlands is nearly as high as that of new bulls that are being sampled in the US. For bulls born during 1988, mean evaluation in the US surpassed means for bulls in France, Italy, and The Netherlands by <250 kg for PTA for milk (Table 5) and by <3 kg for PTA for protein (Table 6).

Correlations between bull economic indexes by country of index (Table 7) generally were high (0.9 to nearly 1.0) except for the US compared with Italy and The Netherlands. Indexes from countries other than the US either did not include milk or gave milk a negative weight (Table 2). This difference had the most apparent consequences for comparisons of the US with Italy and The Netherlands, which had the greatest negative weights for milk yield. Correlations (not shown) of indexes with evaluations for protein yield expressed on the US scale ranged from 0.885 to 0.987; the correlation was lowest for Italy. The high negative weight of Italy for milk yield may reduce emphasis on protein yield through the genetic correlation between milk and protein yields in addition to the intended disincentive for carrier production.

Mean losses from selection on an index other than the official index of the country are in Table 8. For example, when the weights of the official French index are considered to be appropriate, selecting the top 100 bulls based on the weights of the Italian index would reduce the mean index of those bulls by 0.059 standard deviations. The loss from selection on another index was small (≤0.12 SD) when correla-

TABLE 6. Mean international evaluations of Holstein bulls for protein yield on the US scale (PTA) by country with the most daughters of a bull and birth year and mean annual increases in evaluations.

Birth year	Canada	Denmark	Finland	France	Germany	Italy	Sweden	The Netherlands	US
	(kg)								
1976	−17.3	−21.0	−26.6	−21.2	−20.3	−20.0	−24.4	−26.3	−13.5
1978	−17.5	−20.0	−16.1	−16.6	−17.9	−19.2	−21.6	−24.5	−10.6
1980	−15.3	−13.5	−15.4	−16.2	−15.4	−12.9	−21	−19.2	−7.3
1982	−11.4	−16.6	−11.1	−10.0	−13.7	−9.9	−18.7	−14.0	−3.4
1984	−8.4	−12.6	−12.3	−8.0	−12.6	−7.3	−17.9	−8.9	−1.5
1986	−3.7	−6.2	−7.8	−1.2	−7.4	−0.4	−14.8	−3.4	4.1
1988	−2.5	−1.8	−3.7	5.4	−3.4	4.6	−6.2	4.6	7.5
Mean annual increase	1.2	1.6	2.0	2.2	1.4	2.0	1.5	2.6	1.7

TABLE 7. Correlations between economic indexes applied to international Holstein bull evaluations[1] expressed on the US scale by country of index.

Country	Canada	Denmark	France	Germany	Italy	The Netherlands	US
Canada		0.996	0.960	0.998	0.900	0.956	0.963
Denmark	0.996		0.962	0.991	0.926	0.975	0.933
France	0.960	0.962		0.971	0.955	0.977	0.902
Germany	0.998	0.991	0.971		0.897	0.956	0.968
Italy	0.900	0.926	0.955	0.897		0.986	0.761
The Netherlands	0.956	0.975	0.977	0.956	0.986		0.852
US	0.963	0.933	0.902	0.968	0.761	0.852	

[1]Effects of birth year removed.

tions between indexes (Table 7) were high (≥0.95). However, when the correlations were about 0.9, loss was 0.14 to 0.28 standard deviations. The four largest losses were 0.42 to 0.68 standard deviations for comparisons of the US with Italy and The Netherlands. Although any loss is undesirable, 0.1 standard deviations could be considered to be a loss of practical importance because the losses are for estimates of bull merit rather than true bull merit.

Results in Tables 7 and 8 are from application of various indexes to evaluations on a US scale. Because of the high genetic correlation (0.995) assumed between countries, results would have been similar, regardless of the country chosen for the basis of the evaluations. When the index for each country was applied to international evaluations expressed on the scale of that same country (rather than on a US scale), correlations between economic indexes were similar to those in Table 7. A genetic correlation of <0.995 would have reduced correlations between international evaluations (Table 4) but would have had limited impact on results in Tables 5, 6, 7, and 8 because evaluations were expressed on the scale of only one country.

CONCLUSIONS

National and international evaluations differed little for bulls with daughters in only one country. Slight reranking occurred for the few bulls with daughters in multiple countries. The number of multiple-country bulls could be greatly increased by relaxation of the requirement that a bull must be used in a country as a young bull in order for data of his daughters from that country to be included in international evaluations. Documentation of February 1995 evaluations from INTERBULL facilitates comparisons with international evaluations calculated beginning in August 1995, which include relaxation of this requirement and the introduction of variable genetic correlations.

Improvement in genetic merit over time tended to be larger for countries that started with lower genetic merit. Differences among countries in genetic merit of recent bulls have decreased markedly, especially between the US and other countries. The extensive use of US bulls in other countries is likely the primary reason for this change.

Examination of seven national indexes for combining yield data showed that some were similar in

TABLE 8. Mean losses in index for the top 100 bulls among 14,277 Holstein bulls selected on an index other than the official index for that country.

Country of selected index	Country of official index						
	Canada	Denmark	France	Germany	Italy	The Netherlands	US
	SD						
Canada		0.010	0.066	0.004	0.273	0.120	0.112
Denmark	0.011		0.072	0.025	0.212	0.081	0.185
France	0.116	0.110		0.082	0.106	0.065	0.283
Germany	0.005	0.023	0.051		0.273	0.125	0.096
Italy	0.207	0.139	0.059	0.202		0.018	0.550
The Netherlands	0.121	0.068	0.041	0.120	0.022		0.419
US	0.106	0.188	0.168	0.095	0.680	0.433	

impact, although the weights used and traits included were different. Other indexes that were quite different did result in selection of bulls with merit that differed by more than half an index standard deviation. Genetic progress may depend more on the choice of an index for a country or an individual breeder than on the replacement of national with international evaluations.

ACKNOWLEDGMENTS

The national and international evaluations were available through the participation and cooperation of nine countries and the efforts of the INTERBULL Centre (Uppsala, Sweden).

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