Direct and Indirect Conversion of Bull Evaluations for Yield Traits Between Countries[1]

R. L. POWELL
Animal Improvement Programs Laboratory
Agricultural Research Service, USDA
Beltsville, MD 20705-2350

M. SIEBER
National Association of Animal Breeders
Columbia, MO 65205

ABSTRACT

Genetic evaluations of Holstein bulls from the US were matched with Canadian, Italian, Mexican, and Netherlands evaluations for the same bulls. Conversion equations for milk yield were computed by least squares, Goddard, and Wilmink methods. Accuracy was assessed by splitting data and applying equations developed from one subset to the other subset. Methods were judged by mean differences between actual and converted evaluations and standard deviation of that difference. Imperfection of conversions appeared to be due to inherent characteristics (variation and bias) of data rather than to inadequacy of conversion methodology. Least squares was slightly better than other methods but is not recommended by the International Bull Evaluation Service. The Goddard method was generally superior to the Wilmink method, but data often are not available for its application. A variation of the Goddard method was equal in accuracy to the Wilmink method. Daughter yield deviation as both dependent and independent variables was examined for only one data set and was little different from the Goddard method. Indirect equations were quite accurate for US to Mexico and US to the Netherlands but much less accurate for US to Italy conversion. Indirect conversions still would be useful until evaluations of bulls in common allow for direct conversions. For all three countries, a variation on indirect methodology was slightly superior to the usual indirect equations.
(**Key words**: conversion, genetic evaluation, breeding value, transmitting ability)

Abbreviation key: **BCA** = breed class average, **BV** = breeding value, **DYD** = daughter yield deviation, $\mathrm{EVAL_{EXP}}$ = bull evaluation in exporting country, $\mathrm{EVAL_{IMP}}$ = bull evaluation in importing country, **ID** = identification, **INTERBULL** = International Bull Evaluation Service, **REL** = reliability, $\mathrm{REL_{IMP}}$ = reliability in importing country.

INTRODUCTION

A substantial increase in the international exchange of genetic material has taken place over the last 25 yr. International sales of dairy semen in 1990 accounted for 22% of total units sold by members of the National Association of Animal Breeders (3). In 1990, the US exported over 4.1 million units of Holstein dairy semen, which accounted for 90% of exported US dairy semen and over 18% of total units sold by the National Association of Animal Breeders for all dairy breeds. The primary importers of US dairy semen based on units were the European Community (37%), South America (17%), and North America (16%) (3).

As a result of this increased movement of germplasm, genes from the North American Holstein population rapidly are being incorporated in other populations (2, 4, 11, 12). Philipsson (12) estimated that in 1986 over 80% of Netherlands Friesian progeny-tested and young bulls and 50% of first lactation

Received October 28, 1991.
Accepted December 23, 1991.
[1]This research was funded in part by the National Association of Animal Breeders, Columbia, MO and the Deutsche Forschungsgemeinschaft, Bonn, Germany.

cows and all young Italian Friesian cattle had some North American Holstein-Friesian genes. Although Canadian and US genetics were considered together for the Philipsson study (12), Powell (15) reported that half of the Canadian AI bulls born in 1983 were sons of US bulls. For proven bulls that were in active AI use in 1988, Field (5) found US sires for 80% of Canadian Holsteins and 79% of Dutch Friesian.

The most comprehensive comparison of Friesian cattle from different countries has been the Polish study with 10 strains in the mid-1970s that was supervised by the United Nations' Food and Agriculture Organization (9, 10, 20). Philipsson (12) and Jasiorowski et al. (10) cite several other studies conducted on a limited scale with different strains of Friesian cattle. Although those studies increased information available for making breeding decisions, knowledge on genetic differences between populations and genetic trend still is limited.

An important factor in selecting breeding stock and in marketing dairy semen worldwide is reliable conversion formulas for estimating genetic merit of bulls in importing countries. In 1981, the International Dairy Federation recommended the following conversion formula (8):

converted evaluation for importing country = a + b (reported evaluation in exporting country)

where a was the difference in base between the two countries (intercept) and b was the ratio of standard deviations of evaluations in the two countries (scaling factor). In 1983, the International Bull Evaluation Service (INTERBULL) was established by the European Association for Animal Production, the International Dairy Federation, and the International Committee for Recording the Productivity of Milk Animals to standardize bull evaluations across countries for international use (13). A working group of INTERBULL studied various conversion methods (13) and recommended the Goddard method (6) and the Wilmink method as described by Wilmink et al. (22). However, these procedures for conversion of bull evaluations often have been applied only to simulated data or small data sets that did not allow testing or validation of results (12, 13). The most complete comparison of methods (14) found relatively small differences in accuracy between the Goddard and Wilmink methods and that the least squares method was slightly better than either. However, that study used only US and Canadian evaluations calculated before implementation of an animal model and did not include refinements in data set definition later suggested by INTERBULL (7). Similar accuracy for the Goddard and Wilmink methods also has been reported by Swanson and Bellamy (21).

Approaches have been suggested that would provide directly comparable evaluations for multiple countries in a single analysis with the additional benefit of combining information on daughters and relatives across countries. One of these approaches combines national evaluations and male relationships (19). Two obstacles are that 1) evaluations need to be the same scale, so b is required at the outset, and 2) national evaluations need to be deregressed, i.e., in a daughter yield deviation (DYD) form. Recent work with this approach has been reported by Rozzi et al. (18) and Banos and Wiggans (1). Another approach is to have lactation data combined and processed jointly in a multinational analysis. Results of a joint US-Canada study were reported by Robinson and Wiggans (17) and Powell et al. (16). Such joint analysis can have substantial computing and logistics problems as well as political roadblocks but would be a proper goal.

To improve reliability and accuracy of conversion methods, INTERBULL recommended (7) that certain restrictions be placed on data used for comparisons of genetic evaluations between countries. The main restrictions were 1) only data from the most recent official evaluations that include not more than 10 birth years of bulls and have fairly complete representation, 2) a minimum of 20 bulls with evaluations in both importing and exporting countries, 3) a minimum measure of accuracy of 75% in both countries, and 4) a minimum correlation of .75 between evaluations in the two countries. Also, if exchange of semen in both directions has been sufficient, data will be limited to bulls initially sampled in the exporting country.

Conversion equations also are needed for situations for which data are not available for

TABLE 1. Dependent and independent variables for computing regression coefficients in conversion equations by methodology using evaluation (EVAL), reliability (REL), and daughter yield deviation (DYD) in importing (IMP) and exporting (EXP) countries.

Method	Dependent	Independent
Least squares	$EVAL_{IMP}$	$EVAL_{EXP}$
Wilmink	$EVAL_{IMP}$	$(EVAL_{EXP} - \overline{EVAL_{EXP}})(REL_{IMP})$
Goddard	DYD_{IMP}	$EVAL_{EXP}$
$Goddard_1$[1]	$(EVAL_{IMP} - \overline{EVAL_{IMP}})/REL_{IMP}$	$EVAL_{EXP}$
Deviation	DYD_{IMP}	DYD_{EXP}

[1]$Goddard_1$ = Variation of Goddard method.

direct use of Goddard or Wilmink methods, e.g., when imports first are being considered or are in their first few years. For such situations, an indirect procedure can be used if direct conversion equations are available between each country and a third country in common.

The purpose of this study was to test alternative conversion methods on data sets from various countries. Accuracies were examined both for direct and indirect conversion methods.

MATERIALS AND METHODS

Data

Genetic evaluations for Holstein bulls were from Canada (July 1991), Italy (July 1991), Mexico (spring 1991), the Netherlands (October 1991), and the US (July 1991). Animal model procedures were used by all countries. Evaluations for yield were expressed as transmitting abilities in the US (kilograms), Mexico (kilograms), and Canada [breed class average (BCA) points] and as breeding values (BV) in Italy (kilograms) and The Netherlands (kilograms). Milk, fat, and protein data were available and analyzed for all countries except Mexico, for which only milk was reported. For brevity, only results for milk yield are reported. Terminology for measure of accuracy included reliability (REL) and repeatability, but the term REL will be applied for all accuracy measures.

Bulls often have been assigned new identification (ID) numbers when used outside their country of origin. If available, original ID numbers were used except for Canadian bulls, for which US rather than Canadian ID was used. Using a single ID for a bull substantially increased the number of matched evaluations between the US and Canada.

Data were edited based on INTERBULL restrictions (7) except that only 10 herds were required for Mexican bull evaluations. Only for the US and Canada was sufficient bull information available so that conversions could be computed in both directions including only bulls initially used in the exporting country.

Methods

Conversions were computed in the direction of gene flow. Three conversion methods were applied to data sets from each country: least squares, Wilmink, and Goddard. Dependent and independent variables for conversion methods are in Table 1. With least squares, b is produced by regressing bull evaluation in the importing country ($EVAL_{IMP}$) on bull evaluation in the exporting country ($EVAL_{EXP}$). In this study, least squares is applied to unadjusted estimates of genetic merit. Although each of the other methods used a least squares procedure, dependent or independent variables were altered. For the Wilmink method (22), $EVAL_{IMP}$ is regressed on the deviation of $EVAL_{EXP}$ from its mean times REL in the importing country (REL_{IMP}): $(EVAL_{EXP} - \overline{EVAL_{EXP}})(REL_{IMP})$. The Goddard method (6) deregresses $EVAL_{IMP}$ to obtain a mean deviation for daughters (such as DYD) and then regresses that value on $EVAL_{EXP}$. As REL_{IMP} approaches unity, results from the least squares, Goddard, and Wilmink methods converge.

A variation on the Goddard method ($Goddard_1$) has been used by regressing $(EVAL_{IMP} - \overline{EVAL_{IMP}})/REL_{IMP}$ on $EVAL_{EXP}$. The $Goddard_1$ method is useful if a daughter deviation in the importing country (the dependent variable for the Goddard method) is not available. For the Wilmink and $Goddard_1$ methods, subtracting the mean affects b only because REL_{IMP} varies. If REL_{IMP} are equal for all bulls, subtracting the mean has no effect. Although a daughter deviation can be computed with animal model evaluation procedures, only the US and Mexico currently provide DYD as recommended by INTERBULL (7). Therefore, the Goddard method could be applied properly only for the US and Mexico as importing countries. For the Wilmink and $Goddard_1$ methods, a is calculated as $\overline{EVAL}_{IMP} - b(\overline{EVAL}_{EXP})$. For the least squares and Goddard methods, a is the intercept obtained in calculation of b.

The more universal availability of DYD that is anticipated raises the question of whether it would be the appropriate measure in the exporting country as well as in the importing country. In such a deviation method, DYD from the importing country would be the dependent variable, and DYD from the exporting country would be the independent variable. This alternative approach was investigated with data from the US and Mexico.

Reporting equations from different conversion methods and observing how they differ have limited value. The goal of conversions is to predict evaluations of future bulls or bulls not otherwise in data from which equations were derived. Therefore, data sets for each country were divided into two subsets by alternating bulls from a file in ID sequence, which resulted in a range of bull ages and equal or nearly equal numbers of bulls in both subsets. Conversion equations (a and b) were computed from each subset, applied to the other subset, and the degree of error was determined. For example, bulls used for computing official conversion equations for Canada to the US were divided into subsets 1 and 2. Equations for estimating US PTA milk from Canadian BCA milk were developed from data in subset 1. Those equations were applied to BCA from subset 2, and the resulting estimated PTA were compared with actual PTA. The reverse process also was followed: equations developed from subset 2 were applied to subset 1. Criteria for judging the best method were difference (actual minus predicted evaluation) from each subset and the corresponding standard deviation of that difference averaged for the two subsets.

These statistics by themselves are difficult to interpret. Although one method may have the smallest standard deviation, it still is not clear how good that method is. One aid to interpretation is to compare means and standard deviations with those from applying equations to the data from which they were derived. Although this practice normally would be avoided, those mean differences and their standard deviations should provide a gauge of the best that can be expected. By definition, least squares equations applied to the data from which they were derived would have the best possible fit (i.e., mean discrepancy of 0 and smallest possible standard deviation). This method was denoted as least $squares_1$ and used as a standard.

Results from the indirect method for calculating conversion equations were compared

TABLE 2. Numbers of bulls contributing information to conversion equations, mean reliabilities (REL) in the importing and exporting countries, and expected and actual correlation between evaluations.

		Mean REL		Correlations	
Conversion	Number of bulls	Exporting country	Importing country	Expected	Actual
Canada to US	171	.977	.892	.934	.944
US to Canada	141	.981	.917	.948	.902
US to Mexico	67	.977	.812	.891	.909
US to Italy	276	.988	.946	.967	.938
US to Netherlands	214	.947	.925	.935	.891
Canada to Italy	79	.989	.935	.961	.950
Canada to Mexico	51	.973	.821	.894	.907
Canada to Netherlands	53	.961	.948	.954	.913

TABLE 3. Mean differences[1] between actual and converted evaluations for milk yield and their standard deviations for conversion equations developed from one data subset and applied to the other.

Conversion path	Method	$\overline{X}$	SD
Canada to US (PTA, kg)	Wilmink	–1	142
	Goddard	0	136
	$Goddard_1$[2]	–2	143
	Least squares	0	136
	Least $squares_1$[3]	0	135
US to Canada (BCA[4])	Wilmink	.00	2.82
	$Goddard_1$	.00	2.82
	Least squares	.00	2.77
	Least $squares_1$	.00	2.77
US to Italy (BV,[5] kg)	Wilmink	–1	227
	$Goddard_1$	–1	227
	Least squares	–1	225
	Least $squares_1$	0	224
US to Mexico (PTA, kg)	Wilmink	–2	152
	Goddard	–2	136
	$Goddard_1$	–2	152
	Deviation	–2	136
	Least squares	–2	136
	Least $squares_1$	0	135
US to Netherlands (BV, kg)	Wilmink	1	244
	$Goddard_1$	1	245
	Least squares	1	242
	Least $squares_1$	0	239

[1]Actual evaluation minus estimate from conversion equation.

[2]$Goddard_1$ = Variation of Goddard method.

[3]Least $squares_1$ = Least squares applied to same subset from which equations were developed.

[4]BCA = Breed class average.

[5]BV = Breeding value.

with direct results between the US and Italy, Mexico, and the Netherlands. Canada was used as the connecting country. The Wilmink method was used for components of indirect equations and for direct equations with which they were compared. An alternate indirect method ($indirect_1$) was suggested by Goddard (1991, personal communication), because indirect conversion equations tend to be conservative, and combining two direct conversion equations may seriously regress results. In the $indirect_1$ method, b for the equation from the exporting country to the intermediate country is the geometric mean of actual b and one derived from rewriting the equation in the other direction (b_1). For this study, b_1 could be computed only for the US and Canada because they were the only countries with two-way gene flow. Results from the $indirect_1$ method also were compared with those from indirect and direct methods.

RESULTS AND DISCUSSION

Numbers of bulls contributing information to conversion equations and their mean REL in the exporting country and REL_{IMP} are in Table 2 along with expected and actual correlations between evaluations. Mean REL in the exporting country were .95 to .99; REL_{IMP} were lower but all above .80. Expected correlations for milk were computed as square root of the product of mean REL; a genetic correlation of 1 was assumed. Actual correlations were in general agreement with expected correlations except for the Netherlands and US to Canada.

Table 3 presents mean differences between actual and converted evaluations and standard deviations of differences for milk by conversion method. Except for least $squares_1$, data sets were split, and equations developed from one half were applied to the other half. Mean differences were nearly identical for all

TABLE 4. Mean differences[1] between actual and converted evaluations for milk yield and their standard deviations for conversion equations developed from one data subset and applied to the other for bulls with a milk evaluation in the exporting country at least the mean plus one-half the standard deviation.

Conversion path	Method	$\bar{X}$	SD
Canada to US (PTA, kg)	Wilmink	–40	137
	Goddard	–9	137
	$Goddard_1$[2]	–42	137
	Least squares	5	138
US to Canada (BCA[3])	Wilmink	–.80	3.20
	$Goddard_1$	–.77	3.20
	Least squares	–.20	3.16
US to Italy (BV,[4] kg)	Wilmink	–11	237
	$Goddard_1$	–5	237
	Least squares	24	237
US to Mexico (PTA, kg)	Wilmink	–96	157
	Goddard	–29	151
	$Goddard_1$	–96	156
	Deviation	–25	151
	Least squares	–20	151
US to Netherlands (BV, kg)	Wilmink	–19	229
	$Goddard_1$	–24	229
	Least squares	–27	228

[1]Actual evaluation minus estimate from conversion equation.

[2]$Goddard_1$ = Variation of Goddard method.

[3]BCA = Breed class average.

[4]BV = Breeding value.

methods, and standard deviations were nearly the same for the Wilmink and $Goddard_1$ methods. Standard deviation for the Goddard method (Canada to US and US to Mexico) was smaller than for the Wilmink or $Goddard_1$ method. Thus, the Goddard method has an advantage, and efforts to provide DYD so that this method can be used are justified.

Surprisingly, accuracies of the methods, particularly as measured by standard deviation, were only slightly less than for least $squares_1$, which is taken as the optimal simple linear equation. Thus, discrepancies are inherent in the data because of different samples of information and biases. Methodology cannot control or correct for either of those factors. Only small differences between actual and converted evaluations were found for the other methods when conversion equations were applied to the same data set from which they were derived (not reported in table). This further supports that differences between actual and converted evaluations are largely the result of data rather than methods.

Another surprise was that least squares was equal to other methods for mean error and was generally superior to other methods for standard deviation. Least squares is not one of the methods approved by INTERBULL (13) because it generally underestimates b and does not account for REL_{IMP}. However, equation calculation and application using split data sets show it to be unsurpassed, although the Goddard and deviation methods are essentially as good.

Because accuracy of conversion methods is more important for top bulls (those of interest for breeding decisions), mean differences between actual and converted evaluations for milk were examined for bulls with a milk evaluation in the exporting country of at least the mean plus one-half the standard deviation (Table 4). Although selection of this threshold was arbitrary, the mean plus one-half the standard deviation is an objective and convenient procedure to select an elite group that still is large enough (about 31% of total bulls) to yield meaningful results. Mean REL were nearly the same as for all bulls. Equations developed from all bulls in one subset were applied to the top bulls in the other subset. All

TABLE 5. Intercepts(a) and regression coefficients (b) for conversion equations for genetic merit for milk yield by the method of Wilmink et al. (22).

Conversion	a	b
Canada to US	−213 kg	60.1 kg/BCA
US to Canada	4.38 BCA[1]	.01843 BCA/kg
US to Mexico	177 kg	.758
US to Italy	772 kg	1.660
US to Netherlands	673 kg	1.221
Canada to Italy	405 kg	109.8 kg/BCA
Canada to Mexico	−36 kg	41.2 kg/BCA
Canada to Netherlands	374 kg	71.5 kg/BCA

[1]BCA = Breed class average.

methods other than least squares overestimated genetic merit (negative mean difference). Least squares evaluations were both low and high and had differences closest to 0. Where available, converted evaluations from the Goddard method were closer than those from the Wilmink or Goddard_1 methods to the actual evaluations from the other subset according to both mean and standard deviation of difference. Accuracies of the Wilmink and Goddard_1 methods were similar. For these top bulls, the least squares, Goddard, and deviation methods appeared to be superior to other methods.

The a and b for conversion equations for milk by the Wilmink method are in Table 5. These a and b are not official because the importing country has exclusive right and responsibility for establishment of official conversion equations (7). Although these a and b are obsolete for conversions since 1991, they are presented in Table 5 to demonstrate derivation of a and b for the indirect and indirect_1 methods and for comparison with those indirect results. For example, to convert US PTA in kilograms to Netherlands BV, using the indirect method and Canada as the connecting country, the US to Canada and Canada to Netherlands direct conversion equations would be combined:

$$\begin{aligned} \text{BCA} &= 4.38 + .01843(\text{PTA}); \\ \text{BV} &= 374 + 71.5(\text{BCA}) \\ &= 374 + 71.5[4.38 + .01843(\text{PTA})] \\ &= 687 + 1.318(\text{PTA}). \end{aligned}$$

With the indirect_1 method, b_1 for US to Canada conversion would be computed as the square root of .01843(1/60.1) or .01750 BCA/kg. Then the indirect_1 US to Netherlands conversion equation would be

$$\text{BCA} = 4.38 + .01750(\text{PTA});$$

TABLE 6. Mean differences[1] between actual and converted evaluations for milk yield and their standard deviations for conversion equations developed indirectly and directly using the Wilmink method.

Conversion path	Method	$\overline{X}$	SD
US to Italy (BV. kg)	Indirect	−196	283
	Indirect_1[2]	−202	261
	Direct	1	226
US to Mexico (PTA, kg)	Indirect	33	142
	Indirect_1	21	135
	Direct	−6	127
US to Netherlands (BV, kg)	Indirect	−27	255
	Indirect_1	−18	247
	Direct	0	245

[1]Actual evaluation minus estimate from conversion equation.

[2]Indirect_1 = Variation of indirect method.

$$\begin{aligned} BV &= 374 + 71.5(BCA) \\ &= 374 + 71.5[4.38 + .01750(PTA)] \\ &= 687 + 1.251(PTA). \end{aligned}$$

Mean differences between actual and converted evaluations for milk yield and their standard deviations were compared for direct, indirect, and $indirect_1$ methods (Table 6). For evaluation of these conversion methods, split data sets were not used. Therefore, the direct method had the advantage of being applied to the data from which derived. However, the previous results suggest that this would result in little bias in favor of the direct method. Mean differences for the direct method were close to 0 for all three countries. Mean differences were similar for the indirect and $indirect_1$ methods, but standard deviation was less for the $indirect_1$ method. Results from both indirect methods were encouraging for Mexico and the Netherlands, but converted evaluations from indirect methods overestimated genetic merit for Italy. However, even with such overestimation, the converted evaluation would be better than having no comparable information for bulls. Unpublished results using evaluations computed prior to implementation of the animal model were more similar, as mentioned by Swanson and Bellamy (21), who also reported reasonable agreement between direct and indirect equations. For fat and protein, corresponding results were much more similar.

CONCLUSIONS

Conversion equations were essentially as accurate if applied to a separate data set as when applied to data from which they were derived. This indicates that lack of fit is due to the nature of the data (sampling and bias) and not to inadequate methods. Least squares performed well; however, the bulls had high REL, and information from bulls with lower REL might give different results. Where the Goddard method could be applied properly, it generally was superior to the Wilmink method. The Wilmink and $Goddard_1$ methods had similar accuracies.

Computation and distribution of DYD by all countries are important so that DYD can be used for research domestically and internationally. The use of DYD for both dependent and independent variables was examined for only one data set and appeared little different from the Goddard method. These conclusions also were supported by comparing conversion methods for the top bulls.

Indirect equations were quite accurate for US to Mexico and US to the Netherlands conversions. Indirect conversions from the US to Italy were much less accurate but would be preferable to no converted information. In a practical situation, accuracy of the indirect method would not be able to be assessed until a later time when direct data became available. For all three countries, $indirect_1$ equations were superior to indirect equations.

ACKNOWLEDGMENTS

Genetic evaluations were provided by Agriculture Canada, Ottawa, ON; Associazione Nazionale Allevatori Frisona Italiana, Cremona, Italy; and Koninklijk Nederlands Rundvee Syndicaat, Arnhem, The Netherlands. Yield and pedigree data were supplied for US evaluations through the National Cooperative Dairy Herd Improvement Program and for Mexican evaluations through Holstein de México, Queretaro.

REFERENCES

1 Banos, G., and G. R. Wiggans. 1991. Comparison of methods for joint ranking of US and Canadian bulls. J. Dairy Sci. 74(Suppl. 1):231.(Abstr.)

2 Cunningham, E. P. 1983. European Friesians—the Canadian and American invasion. Anim. Genet. Resources Info. 1:21.

3 Doak, G. A. 1991. Page 8 *in* President's report. Proc. Natl. Assoc. Anim. Breeders, San Francisco, CA.

4 Dommerholt, J., C.J.M. Hinks, J. A. Lederer, J. C. Mocquot, P. H. Petersen, K. Rönningen, and G.J.T. Swanson. 1983. General recommendations for the documentation of changes in dairy cattle populations and for estimating the expected genetic merit of bulls of various origins used on specific cow populations. Report of a working group of the E.A.A.P. Commission on Animal Genetics. Livest. Prod. Sci. 10:519.

5 Field, J. D. 1990. Road to genetic progress begins with U.S. Holsteins. Holstein Sci. Rep. 2112009 3M 1/90. Holstein Assoc., Brattleboro, VT.

6 Goddard, M. 1985. A method of comparing sires evaluated in different countries. Livest. Prod. Sci. 13: 321.

7 International Bull Evaluation Service. 1990. Recommended procedures for international use of sire proofs. Int. Bull Eval. Serv. Bull. No. 4. Dep. Anim. Breed. Genet., SLU, Uppsala, Sweden.

8 International Dairy Federation. 1981. IDF recom-

mended procedure for the international comparison of the genetic merit of dairy cattle. Int. Dairy Fed. A-Doc. 64. Int. Dairy Fed., Brussels, Belgium.

9 Jasiorowski, H. A., M. Stolzman, and Z. Reklewski. 1987. International FAO Black and White Cattle strain comparison (1974–84). World Anim. Rev. 62:2.

10 Jasiorowski, H. A., M. Stolzman, and Z. Reklewski. 1988. The international Friesian strain comparison trial, a world perspective. Food Agric. Organ., United Nations, Rome, Italy.

11 Philipsson, J. 1987. Standards and procedures for international genetic evaluations of dairy cattle. J. Dairy Sci. 70:418.

12 Philipsson, J. 1988. Common genetic bloodlines and standardization of information—prospects and problems in the international use of Friesian cattle strains. Page 78 *in* Proc. 7th World Holstein Friesian Conf., Nairobi, Kenya.

13 Philipsson, J., B. Danell, L. R. Schaeffer, M. Schneeberger, H. Schulte-Coerne, and J.B.M. Wilmink. 1986. Procedures for international comparisons of dairy sires—current practice and evaluation of methods. Int. Bull Eval. Serv. Bull. No. 1. Dep. Anim. Breed. Genet., SLU, Uppsala, Sweden.

14 Powell, R. L. 1988. Comparison of procedures to convert sire evaluations between countries. J. Dairy Sci. 71:1609.

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

16 Powell, R. L., G. R. Wiggans, and J.A.B. Robinson. 1991. Comparison of US and Canadian animal model evaluations of the same Ayrshire cows. J. Dairy Sci. 74(Suppl. 1):232.(Abstr.)

17 Robinson, J.A.B., and G. R. Wiggans. 1991. Comparison of Canadian and US animal model bull evaluations of Ayrshire and Jersey yield traits. J. Dairy Sci. 74(Suppl. 1):232.(Abstr.)

18 Rozzi, P., L. R. Schaeffer, E. B. Burnside, and W. Schlote. 1990. International evaluation of Holstein-Friesian dairy sires from three countries. Livest. Prod. Sci. 24:15.

19 Schaeffer, L. R. 1985. Model for international evaluation of dairy sires. Livest. Prod. Sci. 12:105.

20 Stolzman, M., H. Jasiorowski, Z. Reklewski, A. Źarnecki, and G. Kalinowska. 1981. Friesian cattle in Poland. Preliminary results of testing different strains. World Anim. Rev. 38:9.

21 Swanson, G.J.T., and H. J. Bellamy. 1990. Conversion of foreign bull evaluations to United Kingdom Improved Contemporary Comparison equivalents. Br. Cattle Breed Club Dig. 45:37.

22 Wilmink, J.B.M., A. Meijering, and B. Engel. 1986. Conversion of breeding values for milk from foreign populations. Livest. Prod. Sci. 14:223.