MACE for Total Conformation Score of Holstein Bulls from the Netherlands and the United States*

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Introduction

For many years, international genetic comparisons have relied on regression-based conversion formulae using data from bulls used as service sires in both an importing and an exporting country (Goddard, 1985; Wilmink et al., 1986). Analyses using conversion formulae suffer from several limitations, including: 1) the number of sires used jointly by both an importing and an exporting country may be small; 2) biases in conversion formulae may occur due to preferential treatment of offspring from highly-proven foreign bulls; 3) converted breeding value estimates of extreme foreign bulls (which are the bulls of greatest interest) may be of low accuracy and stability, because breeding value estimates of these bulls often fall outside of the range of data used to calculate the conversion formulae, and 4) a genetic correlation of one between traits measured in the importing and exporting countries must be assumed, so differences in definition and measurement of traits across countries cannot be taken into account properly. Full-sib comparisons (Mattalia and Bonaiti, 1993) can reduce biases due to preferential treatment, but the number of bulls available for comparison may be small. Schaeffer (1985) introduced a linear model comparison (LMC) procedure, which takes into account all male genetic relationships among sires across countries. This method allows a greater number of sires to be used in developing international comparisons, but the assumption of unit genetic correlation is still necessary. Schaeffer and Zhang (1993) later extended the LMC procedure such that evaluations within each country could be considered as separate traits with genetic correlations less than one; this method is referred to as the multi-trait across country evaluation (MACE) procedure.

For production traits, measurement procedures are quite consistent across countries, and genetic correlations between observations taken in different countries are generally close to one. For conformation (type) traits, however, trait definitions and measurement procedures can differ substantially among countries. For example, "stature" is measured similarly by both the USA and the Netherlands, but "foot angle" in the United States is measured quite differently from "claw diagonal" in the Netherlands. Thus, an assumption of unit genetic correlation between countries may not be valid for some conformation traits.

The objective of this study was to apply MACE procedures for simultaneous genetic evaluation of Dutch (NLD) and USA Holstein bulls for total score (final type score). Several restrictions on types of sires included in the MACE analysis were considered. MACE breeding value estimates for Dutch bulls were compared with converted estimates (obtained using the Wilmink procedure) and actual USA estimates, when available. Factors which were associated with changes in sire rankings using MACE instead of traditional conversion formulae were assessed.

Data and Methods

In the USA, final score is a subjective measure of a cow's resemblance to an ideal standard; scores range from ranging from 50 to 97 points. Final score is based on five major classification categories: frame, dairy character, body capacity, feet and legs, and udder. The classifier numerically scores each category within a range of 1 to 100 points. Final score is a weighted average of score for the five major categories, calculated as: .25 x FRAME + .20 x DAIRY CHARACTER + .10 x BODY CAPACITY + .15 x FEET AND LEGS + .40 x UDDER. Phenotypic final score records are used directly in calculation of predicted transmitting abilities (PTAs) and daughter type deviations (DTDs) for type in the USA.

In the Netherland, total score is a subjective measurement of the overall appearance of the cow relative to an ideal standard, with scores ranging from 65 to 99. Primary emphasis is on udder and feet and leg traits. Total score data is analyzed with an animal model, and daughter type deviations used in the current project were calculated in this manner. Genetic evaluations are also calculated for the general characteristics of size, dairy character, udder, and feet and legs. Estimated Breeding Values (EBVs) for total score which are reported to the dairy industry are calculated indirectly as the following weighted average of genetic evaluations for the aforementioned general characteristics: .20 x EBV_{SIZE} + .20 x $EBV_{DAIRY\ CHARACTER}$ + .40 x EBV_{UDDER} + .20 x $EBV_{FEET\ AND\ LEGS}$. This weighted average is standardized to a mean of 100 and SD of 4.

Daughter type deviations for total conformation score, which correspond to average deviation of daughters from contemporaries after adjustment for merit of mates and non-genetic factors (VanRaden and Wiggans, 1991), were used as input data for the MACE procedure. Daughter type deviations from Holstein bulls evaluated in the United States in January, 1994 and in the Netherlands in April, 1994 were included. These bulls originated from the USA, the Netherlands, Germany, Canada, Czechoslovakia, France, and Belgium.

Three methods were used to select sires for inclusion in the MACE analysis:

Data set MACE-1:
Bulls with genetic evaluations in the USA were required to meet the following criteria:

1) birth date of bull within the past 15 years
2) birth date of oldest USA progeny within past 10 years
3) at least 10 daughters in 10 herds
4) National Association of Animal Breeders (NAAB) sampling code other than "O" (e.g., bulls which were not AI or multi-herd sampled were excluded);
5) oldest USA progeny born when the bull was 5 years old or younger (e.g., bulls without "first-crop" evaluations in the USA were excluded).

Bulls with genetic evaluations in the Netherlands were required to meet the following criteria:

1) birth date of the bull within the past 15 years.
2) at least 15 daughters in 10 herds;
3) proof type other than "second-crop only", "pedigree index", or "converted" (e.g., bulls which were known not to have first-crop daughters in the Netherlands were excluded);

Data set MACE-2:
Information from "second-crop" daughters of imported bulls which did not have a "first-crop" evaluation in the importing country were also included in the MACE analysis (i.e., restrictions (USA # 5) and (NLD # 3) above were relaxed). Relaxation of this restriction allowed inclusion of proven USA bulls with daughters in the Netherlands and proven Canadian bulls with daughters in the USA and/or the Netherlands.

Data set MACE-2-B:
Bulls which were not proven in an AI or multi-herd sampling program (e.g., breeder or syndicate-proven bulls) were included (i.e., restriction (USA # 4) for U.S.A. bulls was eliminated). This allowed inclusion of proven USA bulls whose initial genetic evaluations did not come from AI progeny testing programs.

Genetic groups were defined by country of origin and year of birth, with separate groups for missing sires and missing maternal grandsires. The following table shows the number of bulls included in the MACE analysis for each of the three data sets:

Table 1. Number of bulls included in each MACE analysis by country of evaluation.

Country	MACE-1	MACE-2	MACE-2-B
NLD only	3069	3170	3151
USA only	6598	6937	7183
NLD and USA	51	118	137
Bulls in analysis	9,718	10,225	10,470
Daughters per bull	95.44	111.92	113.55
Bulls in pedigree file	10,453	10,921	11,182

There were 51 bulls in the MACE-1 analysis which had first-crop progeny in both the U.S. and the Netherlands. These bulls were primarily a result of two actions: 1) occasional importation of semen from young Red and White USA Holstein sires into the Netherlands over the past 10 years, and 2) sales of young sire semen from one major USA AI company into the Netherlands over the past 4-5 years. The additional bulls with both USA and Dutch evaluations in the MACE-2 and MACE-2-B analyses were primarily imported USA bulls with only second-crop progeny in the Netherlands without a first crop evaluation in the USA. The important difference between MACE-2 and MACE-1 is that MACE-2 utilizes information from all of a bull's daughters in both countries. MACE-2 and MACE-2-B analyses included an average of 15% more daughters per bull than the MACE-1 analysis.

A conversion formula for calculation of USA final score PTA from Dutch total score EBV was developed using the Wilmink procedure. A total of 191 bulls (165 USA and 26 Canadian) were included; this analysis gave an R^2 of .64. Converted PTATs on all Dutch bulls were calculated and compared to MACE. The Wilmink formula was: Converted PTA = -17.728 + .174 x Dutch EBV for total score.

Results and Discussion

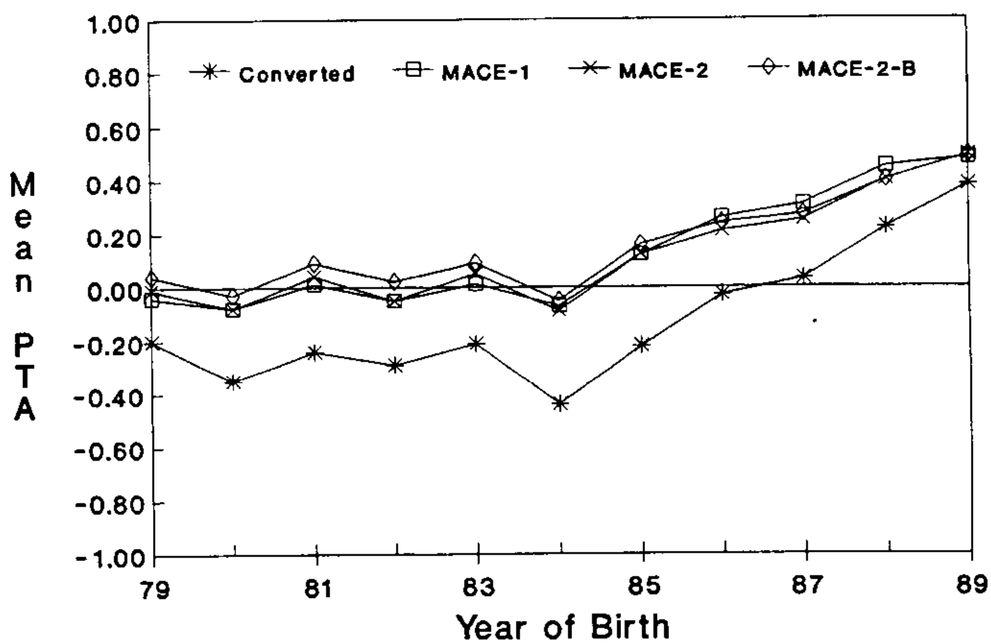
Estimation of the genetic variance-covariance matrix among total conformation score in the USA and Netherlands utilized the REML EM-type estimation procedure of Schaeffer (1994). Genetic variance estimates within each country converged after 8-10 rounds of iteration, but the genetic covariance between total conformation score in the USA and in the Netherlands did not converge after 110 iterations. For this reason, the genetic correlation between total score in the USA and the Netherlands was fixed at .80, which represents the correlation obtained from Wilmink conversion formula analysis of USA predicted transmitting abilities and Dutch estimated breeding values for older, proven bulls with evaluations in both the USA and the Netherlands. After fixing the genetic correlation at .80, several more rounds of iteration were applied to allow within-country genetic variances to stabilize. Further work on procedures for estimation of genetic covariances between countries is needed. The estimated genetic variance-covariance matrix used in the MACE analysis is shown below:

Table 2. Estimated genetic variance-covariance matrix between total conformation score in the USA and the Netherlands.

	USA	NLD
USA	.70094	.17900
NLD	.17900	.07142

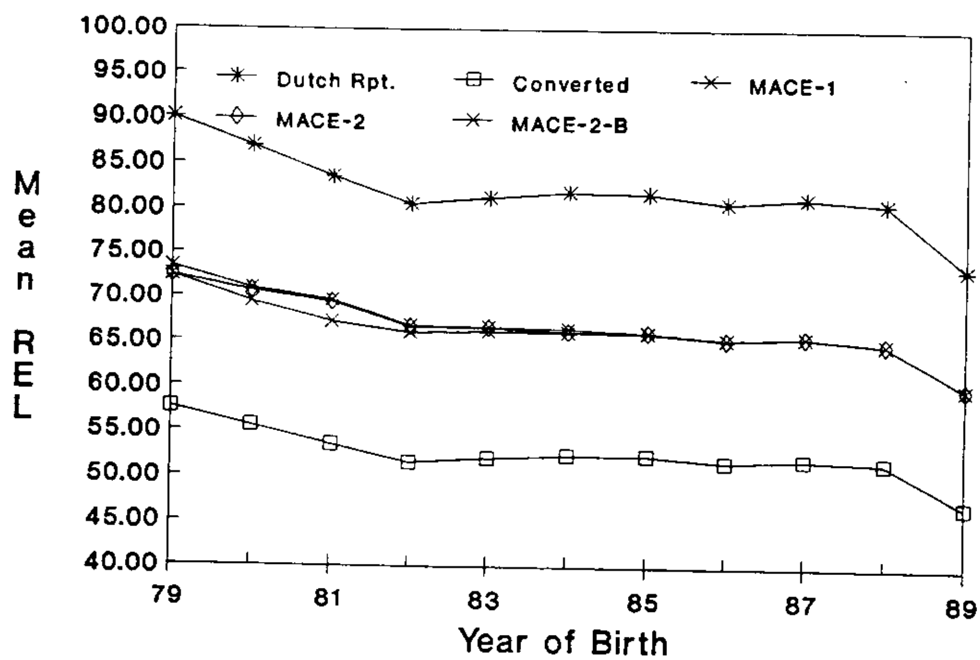
Each of the bulls included in the analysis obtained a MACE breeding value estimate for Dutch total score EBV and for USA final score PTA. MACE PTAs for USA final score for the Dutch bulls were compared with converted PTAs obtained using the Wilmink procedure. In the following graphs, average USA final score PTA and reliability (REL) is shown by year of birth for all Dutch bulls included in the MACE analysis.

Figure 1. Average final score PTA for bulls evaluated in the Netherlands, expressed on a USA basis, using MACE analyses and Wilmink conversion procedures.



As shown in Figure 1, MACE PTAs for Dutch bulls were consistently higher than converted PTAs. Because all exchange of genetic material in the past has been from the USA to the Netherlands, one may hypothesize that daughters of highly proven USA bulls have received preferential treatment in the Netherlands. Such preferential treatment, if it exists, would bias converted PTAs of Dutch bulls downward. MACE analysis may be able to account for such preferential treatment through usage of genetic relationships among bulls; this would explain the differences in average PTA shown in Figure 1 and in Table 3.

Figure 2. Average converted and MACE reliability of final score evaluations, expressed on a USA basis, for bulls evaluated in the Netherlands.



Average reliability of MACE evaluations was about 15% lower than Dutch repeatability values for these bulls. This decrease reflects the loss in information due to differences in trait definition, measurement procedures, and genetic evaluation systems between the USA and the Netherlands. Such differences result in a genetic correlation between Dutch total score and USA final score which is less than one. However, MACE reliability values were nearly 15% larger than converted reliability values, which were calculated as (Dutch repeatability * genetic correlation^2), due to a substantial gain in information through inclusion of genetic relationships among bulls.

Of the 3120 total bulls with evaluations in the Netherlands in data set MACE-1, 601 bulls had sire, dam, and maternal grandsire (MGS) with genetic evaluations in the USA. For these bulls, MACE and converted evalutions were compared with USA parent average. Results are shown in Table 3:

Table 3. Means of genetic information for all Dutch bulls and for 601 Dutch bulls with USA parents.

	Means for Bulls Evaluated in the Netherlands	
	All bulls	Bulls with USA parents
Dutch EBV	101.2	103.6
Dutch DTD	.16	.29
USA Parent Average	...	.55
USA Sire PTA	...	.36
USA Dam PTA	...	.75
USA MGS PTA	...	.27
Converted PTA	-.12	.31
MACE-1 PTA	.15	.40
MACE-2 PTA	.13	.36
MACE-2-B PTA	.16	.36

Data set MACE-1 led to slightly higher average MACE PTA of Dutch bulls than data set MACE-2, which included data from second crop daughters of proven bulls with imported semen. However, differences among MACE analyses were much smaller than the difference between MACE and conversion formula analyses. It should be noted that within the USA, there is "pedigree slippage" of about -.11 points in final score. Pedigree slippage is the average amount that the parent average overpredicts the eventual PTA. Therefore, it appears that very little bias exists in MACE PTAs.

In Table 4, correlations among MACE PTAs, converted PTAs, Dutch EBVs and Dutch DTDs are shown. As expected, correlations of Dutch EBV and DTD values with MACE PTAs (.91 to .93) were smaller than with converted PTAs (.97 to 1.00). This occurs because the

MACE procedure places more emphasis on foreign information from a bull's relatives in other countries than does a conversion formula, which relies entirely on performance of daughters in the importing country. Correlations among MACE PTAs using different data selection procedures were near one.

Table 4. Correlations among MACE PTA and converted PTA (CONV) values for all 3120 bulls evaluated in the Netherlands.

	EBV	DTD	CONV	MACE-1	MACE-2	MACE-2-B
EBV	1	.97	1	.93	.91	.91
DTD		1	.97	.95	.94	.93
CONV			1	.93	.91	.91
MACE-1				1	.99	.98
MACE-2					1	.99
MACE-2-B						1

For Dutch-proven bulls whose sire and dam had been evaluated in the USA, it was possible to examine the effect of relatives' information on differences between MACE and converted PTA values. In the following table, correlations between parent average and sire, dam, and maternal grandsire PTA with the quantity: (MACE PTA - converted PTA) are shown. As expected, changes in PTA observed when using MACE analyses instead of a conversion formula were highly related to PTA values of relatives, particularly sires. The correlation between this change and sire PTA increased when imported and breeder-proven bulls were included in the MACE analysis. This indicates that the inclusion of "second-crop" DTD information from daughters in the Netherlands caused MACE evaluations to be more highly correlated with sires' USA PTAs.

Table 5. Correlations between genetic information from relatives and the quantity: (MACE PTA - converted PTA) for 601 Dutch bulls with USA parents using three data selection procedures.

	Correlation with Deviation from Converted PTA		
	MACE-1	MACE-2	MACE-2-B
PA	.19	.28	.31
Sire PTA	.28	.37	.42
Dam PTA	-.05	-.02	-.03
MGS PTA	-.01	.01	-.01

In the following table, average MACE and converted PTA values are shown by sire of bull. All sires with 15 or more proven sons in the Netherlands were included; both USA and Canadian sires were represented.

Table 6. Average MACE PTA and converted PTA by sire of bull.

			Average PTA		
Sire	No. Sons	Converted	MACE-1	MACE-2	MACE-2-B
ENHANCER	15	-.03	.51	.51	.38
CHIEF	22	-.16	-.26	-.25	-.24
VALIANT	27	.34	.64	.57	.61
SEXATION	15	.67	.78	.71	.70
ROTATE	28	.19	.28	.29	.28
MARK	32	.60	1.17	1.17	1.19
NED BOY	34	.83	.45	.47	.30
MERIT	17	-.31	-.13	-.26	-.26
JESSE	15	.53	.50	.29	.29
SECRET	34	.39	.55	.44	.45
CLEITUS	48	1.12	.89	.98	.99
MELWOOD	15	.80	.84	.90	1.23
BELL TROY	48	.46	.15	.19	.18

Certain sire progeny groups were evaluated more highly when using a conversion formula, which considers Dutch information only, than when using a MACE analysis, which also considers USA genetic evaluations of relatives. This suggest that certain sire families perform much differently under the Dutch classification system than under the USA system. The two sires whose sons rank much lower in the Netherlands (ENHANCER AND MARK) are known for transmitting low foot angle. It appears that low scores for this trait are penalized more severely under the Dutch classification system than under the USA system. Sons of CLEITUS experienced the largest decrease when comparing MACE results with converted Dutch evaluations. CLEITUS transmits several attributes which appear to be favored by the Dutch system, including smaller size, shallower udders, and more slope to the rumps. Average MACE evaluation of sons of one bull (MELWOOD) changed significantly using data set MACE-2-B, because this bull was breeder-proven. It appears that excluding data of Melwood's daughters severely affects both the MACE PTA of MELWOOD and the MACE PTAs of his sons.

To investigate the hypothesis that specific linear type traits can explain the differences between MACE and converted PTAs, correlations between the change in evaluation and the sire's linear type trait evaluation were examined. Using all bulls with parents evaluated in the USA, the correlation between sires' linear trait PTAs and sons' change in PTA using MACE instead of a conversion formula was calculated. Results are shown in Table 7.

Table 7. Correlation between the deviation: (MACE PTA - converted PTA) and sires' linear type trait PTA for 601 Dutch bulls with USA parents.

Sire's linear PTA	Correlation with Deviation from Converted PTA		
	MACE-1	MACE-2	MACE-2-B
Stature	.22	.32	.35
Strength	.39	.42	.41
Body Depth	.38	.41	.41
Dairy Form	.15	.20	.27
Rump Angle	-.38	-.30	-.29
Thurl Width	.47	.46	.45
Rear Leg Set	.33	.33	.31
Foot Angle	-.25	-.21	-.13
Fore Udder Attachment	.23	.32	.33
Rear Udder Height	.33	.39	.40
Rear Udder Width	.51	.51	.51
Udder Cleft	.08	.11	.16
Udder Depth	-.08	.11	.16
Front Teat Placement	.02	-.07	-.03

Based on information in the above table, it appears that the USA classification system favors larger cattle with stronger fore and rear udder attachments, while the Dutch system favors somewhat smaller cattle with sloped rumps, straighter rear legs, and a steeper foot angle. It is clear that pedigree information strongly influences MACE PTAs and that certain aspects of conformation are measured and weighted differently in the USA as compared to the Netherlands.

Fifty-one bulls were "dual-proven", i.e., these bulls had genetic evaluations based on first-crop progeny in both the USA and the Netherlands. As these bulls have official USA genetic evaluations, it was possible to compare both converted and MACE PTAs to their actual USA PTAs. For the purposes of comparison, the MACE analyses were repeated after exclusion of the US DTD information for these bulls. Thus, it was possible to compare converted and MACE PTAs which were not influenced by USA daughter information, i.e., as if these bulls did not yet have daughters in the USA. Results are presented in Table 8.

Table 8. Bias (average deviation from USA PTA) and mean squared error (MSE = average squared deviation) for bulls with first-crop evaluations in both the USA and the Netherlands (n = 51).

With USA DTD information for dual-proven bulls in MACE analysis:

	Converted	MACE-1	MACE-2	MACE-3
BIAS	-.188	-.057	-.061	-.059
MSE	.382	.032	.033	.032

Without USA DTD information for dual-proven bulls in MACE analysis:

	Converted	MACE-1	MACE-2	MACE-3
BIAS	-.188	.044	.015	.017
MSE	.382	.375	.378	.375

Without dual-proven bulls in calculation of conversion formulae:

	Converted	MACE-1	MACE-2	MACE-3
BIAS	-.252	.044	.015	.017
MSE	.412	.375	.378	.375

As expected, when USA daughter type deviation information for these dual-proven bulls is used, MACE evaluations are much closer to actual PTAs than are converted evaluations. This would indicate a significant advantage to MACE procedures in situations where many bulls are progeny tested in two or more countries simultaneously. Such "joint" progeny testing systems are becoming more common; for example, several young Canadian bulls have recently been enrolled in USA sire evaluation for type program. However, most bulls which are progeny tested within a particular country will have little or no progeny test semen distributed to other countries. When USA DTD information for dual-proven bulls was removed from the MACE analysis, mean squared error was slightly smaller for MACE than for converted evaluations. However, bias was substantially smaller using the MACE procedure; presumably this procedure is able to partially account for preferential treatment through extensive use of genetic relationships. Many of these dual-proven bulls were part of the data set used to develop the Wilmink conversion formula, and exclusion of these bulls from calculation of the conversion formula resulted in larger negative bias and larger MSE, because the new conversion formula was based entirely on information from proven bulls with only second-crop progeny in the Netherlands.

Summary

The MACE procedure seems to be superior to the Wilmink procedure in terms of bias and accuracy of international evaluations. For Dutch bulls with USA parent averages, MACE evaluations had less negative bias than converted evaluations (Table 3). After accounting for pedigree slippage, MACE evaluations were essentially unbiased. Furthermore, both bias and MSE of MACE evaluations were smaller than for converted evaluations for 51 "dual-proven" bulls (Table 8). Because the MACE procedure includes more sires and utilizes genetic relationships among bulls, reliability of MACE evaluations is higher than reliability of converted evaluations (Figure 1).

Data set MACE-2 included second-crop daughter information from the importing country. Usage of this information will greatly aid in promoting MACE as an international evaluation procedure, because all daughters of a bull worldwide can be included. This leads to a substantially higher number of daughters per bull (Table 1). The current study does not show any evidence of larger bias or MSE when using data set MACE-2 instead of MACE-1 (Tables 3 and 8). Imported bulls with daughters in multiple countries provide the strongest direct ties between countries for international comparisons. Currently, international comparisons using conversion formulae rely almost entirely on second-crop daugther information from imported proven bulls; results of the current study indicate that exclusion of such information from future MACE analyses does not seem warranted. Surprisingly, inclusion of information from second-crop Dutch daughters of proven USA bulls resulted in MACE evaluations which were less correlated with Dutch EBVs for bulls proven in the Netherlands (Table 4) and more closely related to their USA parent averages (Table 5).

Results from the present study (Tables 3, 5 and 8) would support the use of daughter information from high reliability breeder proven bulls (data set MACE-2-B). In fact, exclusion of this information for a popular proven sire will severely affect the MACE evaluations of his sons (Table 6).

Differences between MACE and single country evaluations will need to be explained to breeders. Because the current study uses data for a cow's overall final score, changes in evaluations can be explained by differences in trait definition and preference between the two countries. Examination of linear type trait information aids in identifying specific differences (Table 7).

Recommendations

MACE procedures for international genetic evaluation of conformation traits may offer several advantages relative to traditional conversion formulae. First, changes in sire rankings allowed by the MACE procedure can account for differences in trait definitions and measurement procedures across countries (i.e., a "genotype x trait definition" interaction). Such differences are likely to be small for production traits, but differences in measurement of certain type traits between countries may be substantial. Second, incorporation of pedigree information using the MACE procedure can result in substantial increases in reliability of evaluations for foreign bulls. Third, through incorporation of both domestic and foreign evaluations of relatives, the MACE procedure is less susceptible to biases due to preferential treatment of progeny of highly proven foreign bulls. Finally, inclusion of all available daughter information in the MACE analysis seems to be warranted, because second-crop daughter information for imported bulls is very useful for making direct international comparisons, and utilization of domestic daughter information for breeder-proven bulls can increase the accuracy of MACE evaluations for certain sire families.

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References

Goddard, M. 1985. A method of comparing sires evaluated in different countries. Livestock Production Science 13:321.

Mattalia, S., and B. Bonaiti. 1993. Use of full sibs families to estimate the 'a' coefficients of conversion formulas between countries. INTERBULL meeting, Arhus, Denmark, August 19-20, 1993.

Schaeffer, L. R., and W. Zhang. 1993. Multi-trait, across country evaluation of dairy sires. INTERBULL meeting, Arhus, Denmark, August 19-20, 1993.

Schaeffer, L. R. 1994. MACE for dairy sires from four countries. Unpublished manuscript, Department of Animal Science, University of Guelph, ON, Canada.

VanRaden, P. M., and G. R. Wiggans. 1991. Derivation, calculation, and use of national animal model information. Journal of Dairy Science 74:2737.

Wilmink, J. B. M., A. Meijering, and B. Engel. 1986. Conversion of breeding values for milk from foreign populations. Livestock Production Science 14:223.