Multiple Lactation Random Regression Test-Day Model for Simmental and Brown Swiss in Germany and Austria

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Introduction

In summer 2000 the countries Germany (DEU) and Austria (AUT) started to join genetic evaluation for Simmental and Brown Swiss cattle. As the breeding goals in both countries are similar the breeding animals could be selected across countries, leading into higher genetic progress due to the enlarged population size. Joint evaluations were first realised for conformation traits and functional longevity in 2001 and in 2002 evaluations for milkability, somatic cell score, fertility, calving ease, stillbirth, growth and carcass traits will follow. An introduction of a joint evaluation for the production traits milk, fat and protein yield is scheduled in November 2002.

During recent years random regression test-day models (RR-TDM) have been introduced for genetic evaluation of milk production traits in few countries (e.g. Schaeffer *et al.,* 2000, Lidauer *et al.,* 2000, De Roos *et al.,* 2001). The development of a RR-TDM for joint evaluation of DEU and AUT was started at the Bavarian Institute of Animal Production in Grub in collaboration with the animal breeding group from MTT Finland. Aim of the project was to develop a multiple lactation model, where first, second and third lactations are defined as correlated traits and the biological traits milk, fat and protein yield are estimated in separate runs. The inclusion of test-day records from all lactations was favored strongly by practical breeders. Because the scope of the evaluation comprised of relatively different herd environments (climate, topography, herd management) heterogeneous variances should be accounted for in the joint evaluation.

Objectives of this presentation are to describe the estimated variance components, the developed RR-TDM, the data used in the test run March 2002, and to compare the new breeding values with those from current multiple lactation models in DEU and AUT. A description of the procedure for accounting of heterogeneous variances will be given in another presentation (Lidauer *et al.,* 2002*a*) and is also described in Lidauer *et al.* (2002*b*).

Material and Methods

Data

Test-day (TD) data from DEU and AUT described here were used for the Interbull test run in March 2002. Data consisted of TD records from all lactations between days in milk 8 to 350 from the time period January 1990 to 2002. In 1990 and 1991 records were accepted only if cows had observations from the first lactation. In the following years cows with missing first lactation were excluded, if no cows with equal parity and first lactation TD records were found in data. The ratio of TD records from DEU and AUT was 82:18 and 77:23 for Simmental and Brown Swiss, respectively. Data sets consisted of 4.35 mill. (0.93 mill.) cows with 11.7 mill. (2.6 mill.) lactations and 92.5 mill. (22.0 mill.) TD records for Simmental (Brown Swiss); 76 and 74 percent of lactations came from first to third parity in Simmental and Brown Swiss data, respectively. TD records were measured on 7.85 (2.49) mill. herd test-days (HTD), which correspond to an average number of 11.8 and 8.8 TD records per HTD in Simmental and Brown Swiss data, respectively. The joint pedigrees included 6.46 mill. and 1.55 mill. animals for Simmental and Brown Swiss, respectively. In both evaluations the unknown parents were described by 111 phantom parent groups categorized by country, time period and selection path.

Model

TD observations from all lactations were analysed with the following multiple-lactation reduced rank RR-TDM:

$$
\begin{bmatrix} y_{Fijklmnopq}\lambda_{Fijk} \\ y_{Sijklmnopq}\lambda_{Sijk} \\ y_{Lijklmnopqr}\lambda_{Lijkl} \end{bmatrix} = htd_i + \begin{bmatrix} (pymr)_{Fjk} \\ (pymr)_{Sjk} \\ (pymrl)_{Ljkl} \end{bmatrix} + \begin{bmatrix} \sum_{s=1}^{2} age^s b_{1Fms} \\ \sum_{s=1}^{2} age^s b_{1Sms} \\ \sum_{s=1}^{2} age^s b_{1Lmns} \end{bmatrix} + \begin{bmatrix} \sum_{s=1}^{3} dcc^s b_{2Fms} \\ \sum_{s=1}^{3} dcc^s b_{2Sms} \\ \sum_{s=1}^{3} dcc^s b_{2Llms} \end{bmatrix} + \begin{bmatrix} \phi(DIM) b_{3Fmo} \\ \phi(DIM) b_{3Smo} \\ \phi(DIM) b_{3Llmo} \end{bmatrix}
$$

$$
+ \begin{bmatrix} \sum_{s=1}^{7} s(DIM)_{Fs} a_{ps} \\ \sum_{s=1}^{7} s(DIM)_{Ss} a_{ps} \\ \sum_{s=1}^{7} s(DIM)_{Ls} a_{ps} \end{bmatrix} + \begin{bmatrix} \sum_{s=1}^{8} t(DIM)_{Fs} p_{ps} \\ \sum_{s=1}^{8} t(DIM)_{Ss} p_{ps} \\ \sum_{s=1}^{8} t(DIM)_{Ls} p_{ps} \end{bmatrix} + \begin{bmatrix} \\ \\ \sum_{s=1}^{4} u(DIM)_{Ls} w_{qs} \end{bmatrix} + \begin{bmatrix} e_{Fijklmnopq} \\ e_{Sijklmnopq} \\ e_{Lijklmnopqr} \end{bmatrix},
$$

where $y_{Fijklmnopq}$, $y_{Sijklmnopq}$ and $y_{Lijklmnopqr}$ are the first, second and later (≥ 3) lactation TD yields and λ_{Fijk}, λ_{Sijk} and λ_{Lijkl} are multiplicative adjustment factors (see also Lidauer *et al.,* 2002*a*). The same model was used in separate runs for the biological traits milk, fat and protein yield. The fixed effects are herd test-day (htd); production year-month j within sub region k (k=1,..,15) and for later lactations within lactation group l (pymr), where l=3 and l=4 for third and fourth and l=5+ for fifth and later lactation records; second order polynomial regression on age at calving (age) within region m (m=1,…, 6) in lactation 1 to 4, and a parity effect for higher (≥ 4) lactations (n=3,…, 9+); third order polynomial regression on days carried calf (dcc) within region m and for later lactations within lactation group l; and the regression coefficients on days in milk (DIM) b_3. The lactation curves were nested within calving year-seasons (12*4), regions m and lactation groups l for later lactations. The covariables $\phi(DIM) = [c1\ c2\ c3\ c4\ c5]$, where c1, c2, c3 represents quadratic Legendre polynomials for DIM, and c_4 and c_5 are exponential terms exp(-p_1DIM) and exp(-p_2DIM), where p1 is 0.06, 0.04 and 0.02 for milk, fat and protein, respectively, and p2 is 0.01 [0.02, 0.02], 0.02 [0.03, 0.03] and 0.19 [0.18, 0.17] for first [second, later] lactation milk, fat and protein, respectively. The region classes m were defined as four (two) regions in Bavaria and one (one) region in Baden-Württemberg and Austria in the Simmental (Brown Swiss) data. The definition of sub region codes k was chosen more detailed, because the production year-month-region$_k$ classes were defined as strata in the heterogeneous variance correction. Here 9 (3) regions in Bavaria, 2 (1) regions in Baden-Württemberg and 4 (4) regions in Austria were defined in the Simmental (Brown Swiss) data. Observations were classified into 8674 and 4440 in production year-month-region classes and 1170 and 780 lactation curve classes in the Simmental and Brown Swiss data set, respectively. Modelling of the herd test-day effect as a fixed effect across lactations was found advantageous in populations with small herd sizes (Emmerling *et al.,* 1999).

Random effects are the RR-coefficients a_{p1}, …, a_{p7} for additive genetic effects of first, second and later lactations, p_{p1}, …, p_{p8} for non-genetic animal effects across first, second and later lactations, w_{q1}, …, w_{q4} for non-genetic animal effects within each of third and later lactations and the residual effect e. The breeding value of cow p in first lactation can be calculated as $\sum_{s=1}^{7} \mathbf{s}(DIM)_{Fs} a_{ps}$, where $\mathbf{s}(DIM)_{Fs}$ is a specific set of covariables corresponding to days in milk DIM, which is described in the section about variance components. The non-genetic animal effect across lactations is of similar structure as the additive genetic effect, but with a different set of covariables, e.g. $\mathbf{t}(DIM)_{Fs}$ for first lactation. For accounting of non-genetic effects within later lactations the function $\sum_{s=1}^{4} \mathbf{u}(DIM)_{Ls} w_{qs}$ is included, which models the repeatability of later lactations. Thus the genetic value of an animal is described by 7 RR-coefficients, and the non-genetic effects across lactation by additional 8 RR-coefficients plus 4 coefficients for each of third and later lactations.

Let a be **a** vector of all additive genetic animal effects, **p** be a vector of non-genetic animal effects across lactations, **w** be a vector of non-genetic animal effects within lactations and **e** be a vector of all residuals. The covariance matrix of these random effects was assumed to be

$$\mathrm{var}\begin{bmatrix}\mathbf{a}\\ \mathbf{p}\\ \mathbf{w}\\ \mathbf{e}\end{bmatrix}=\begin{bmatrix}\mathbf{A}\otimes\mathbf{D_a} & 0 & 0 & 0\\ 0 & \mathbf{I}\otimes\mathbf{D_p} & 0 & 0\\ 0 & 0 & \mathbf{I}\otimes\mathbf{D}_\mathrm{w} & 0\\ 0 & 0 & 0 & \mathbf{R}\end{bmatrix},$$

where **A** is the numerator relationship matrix, $\mathbf{D_a}$, $\mathbf{D_p}$ and $\mathbf{D_w}$ are covariance matrices from covariance functions (CF), and R is the (co)variance matrix for the measurement error.

Variance components

The covariance matrices $\mathbf{D_a}$, $\mathbf{D_p}$, $\mathbf{D_w}$ and **R** were derived with a two step approach (Mäntysaari, 1999), described in detail by Emmerling *et al.* (2002). In the first step (co)variance parameters for additive genetic and residual effects of seven time periods (DIM 8-20, 31-63, 64-96, 130-162, 196-228, 262-294 and 295-326) in first, second and third lactation were estimated. For two Simmental samples and the biological traits milk, fat and protein yield a total of 270 four-trait animal model REML runs were performed. Estimates were combined with an algorithm for iterative summing of expanded part matrices (Mäntysaari, 1999). This resulted in (co)variance matrices for additive genetic and residual effects with dimension 21 by 21. Second order Legendre polynomials (Kirkpatrick *et al.*, 1990) plus an exponential term as given by Wilmink (1987) were used to derive CFs based on these matrices by the method described in Emmerling *et al.* (2002). Rank of resulting CFs was reduced by analysing eigenvalues of CFs within and over lactations. Rank was reduced to 7 and 8 for additive genetic ($\mathbf{D_a}$) and non-additive genetic CFs ($\mathbf{D_p}$), respectively. The same degree of reduction was applied in derivation of milk, fat and protein CFs. For within later lactations CF of non-genetic animal effects rank was not reduced and therefore $\mathbf{D_w}$ had rank 4.

Corresponding eigenfunctions of dominant eigenvalues were combined with covariables from Legendre polynomials and exponential term which resulted in matrices **S** and **T**. These matrices can be partitioned in $\mathbf{S}=[\mathbf{S'_F}\ \mathbf{S'_S}\ \mathbf{S'_L}]$ and $\mathbf{T}=[\mathbf{T'_F}\ \mathbf{T'_S}\ \mathbf{T'_L}]$, where e.g. $\mathbf{S_F}$ contains the (additive genetic) covariables for first lactation yields with $\mathbf{S_F}=[s(8)_\mathbf{F}\ \ s(9)_\mathbf{F}\ \ldots\ s(350)_\mathbf{F}]'$. With these covariables genetic or phenotypic (co)variances for any DIM can be calculated, e.g. covariance between day i and j within first lactation $\sigma_{(\mathbf{i,j})\mathbf{F}}=s(i)_\mathbf{F}\mathbf{D_a}s(j)_\mathbf{F}$, where dimension of $\mathbf{D_a}$ is seven by seven. In Table 1 heritabilities, genetic and phenotypic correlations for milk, fat and protein yield across lactations are shown for six arbitrarily chosen DIM per lactation. Constructed 305-day heritabilities based on 10 test-days (DIM 14, 47, 80, …, 311) were 0.36 (0.31, 0.27), 0.32 (0.30, 0.27) and 0.33 (0.27, 0.27) for first, second and later lactation milk (fat, protein) yield, respectively. Genetic correlations of 305-day lactation yields were .93 (fat .94 / protein .91) between first and second lactation milk, over .91 (.92 / .87) between first and later lactation and .98 between second and later lactation (.98 / .98). The repeatability of later (305-day) lactations was .63, .59 and .58 for milk, fat and protein, respectively.

Breeding value estimation

March 2002 test run consisted of 106.5 mill. equations in the Simmental and 25 mill. in Brown Swiss TD evaluation systems. Equations were solved using MiX99 software (Lidauer & Stranden, 1999). Iterations were performed on an IBM 6F1 with 16 GB random access memory (RAM) and 6 processors, where about 5.5 GB RAM were used for the program itself (PCG vectors) and about 6 GB were used for temporary caching of data files in Simmental evaluation. The convergence statistic was the square root of the relative difference between left-hand and right-hand side, which had to be smaller than 3.0×10^{-7} in order to have convergence.

To get breeding values for 305-day yields of first, second and third lactation the seven estimated breeding value coefficients in $\hat{\mathbf{a}}$ were used, e.g. for first lactation milk yield of cow i: $\mathrm{EBV}_{\mathrm{Fi}}=1'\mathbf{S_F}\hat{\mathbf{a}}_\mathbf{i}$, where $\mathbf{S_F}$ are the covariables of DIM 8 to 312. The same breeding value coefficients are used to calculate the EBVs for first, second and third lactations within the biological traits, only the set of covariables has to be changed.

Results and Discussion

Estimated heritabilities are in a similar range as found in other publications (e.g. Lidauer *et al.*, 2000; Liu *et al.*, 2000), but significantly lower compared to parameters presented by De Roos *et al.* (2002). The difference between first and later lactation heritabilities for milk yield is not as large as in these comparable studies. High genetic correlations between second and third lactation TDs were also reported by Liu *et al.* (2000). The declining heritabilities for fat yield in the first 50 days in milk on all three lactations were consistent with results of Lidauer *et al.* (2000) and De Roos *et al.* (2002), whereas Liu *et al.* (2000) reported very smooth curves in the first weeks of lactation. Apart from breed differences, one explanation might be, that the first time period at the beginning of the lactation was chosen shorter in the REML analyses of our study, in order to be able to get the information about changes in variance parameters in this period. The combination of Legendre polynomials and an exponential term applied here was found to be flexible and advantageous compared to plain Legendre polynomials. The reduction of rank was done quite conservatively; especially for fat and protein a further reduction of rank seemed to be possible. On the other hand, correlation structure was found to be relatively sensitive against rank reduction and therefore only a minimum reduction of rank was preferred. The described variance parameters were applied for the both, Simmental and Brown Swiss, test evaluations in March 2002.

A description of the multiplicative mixed model for accounting of heterogeneous variances is given by Lidauer *et al.* (2002*a*) and Lidauer *et al.* (2002*b*). First test runs of the Simmental evaluation required about two days of computation time. Standard deviations (SD) of EBVs from the March 2002 test run are shown in Table 2. SDs of test-day model EBVs increase from first to third lactation, which was expected considering the applied genetic parameters. In preliminary test runs without accounting for heterogeneous variances the SD of EBVs were clearly higher. Further analyses are necessary to clarify the reasons for the differences in SD between breeding values of German and Austrian bulls.

Correlations between EBVs from TD model and lactation model evaluation are shown in Table 3. The correlations were generally higher for bulls (Simmental 0.90 to 0.96 and Brown Swiss 0.89 to 0.96) compared to correlations of cow EBVs. In the current lactation model of Austria the contemporary group is defined in a different (unfavourable) way than in the German evaluation. This might be a reason for the lower correlations between EBVs from TD model evaluations and the former systems.

Conclusions

The presented reduced rank multiple lactation random regression test-day model was found to be applicable for the joint German and Austrian Simmental and Brown Swiss cattle populations. The reduction of rank of derived covariance functions have reduced the number of equations per animal considerably. For a cow with three lactations 7 additive genetic and 12 non-genetic random regression coefficients were estimated instead of 12 plus 16 coefficients in case of full parameters. Additionally, a positive influence of rank reduction was observed on convergence, which was also reported by Strandén *et al.* (2000).

The transition from national lactation models to the joint test-day model will enable the two countries to use the enlarged joint population for selection. Especially for bulls tested jointly by German and Austrian AI-stations the joint evaluation can be regarded as a clear improvement.

The introduction of the test-day model will affect the ranking of bulls and especially of cows, which can be expected from the presented correlations. The main reasons for these changes are the improvements in the accounting for environmental effects on test day level, the accounting for heterogeneous variances and the new definition of breeding values. For fully proven bulls the latter reason has not as large influence as for young bulls, where only little yield information is available. In addition, the possibility of extracting information about persistency from the estimated RR-coefficients is a very desirable property of RR-TDMs. All these changes together can be seen as a milestone in breeding value estimation of Simmental and Brown Swiss cattle in Germany and Austria. The official introduction of the joint test-day model is planned for November 2002. Before that, the estimation of covariance parameters for Brown Swiss, the definition of a breeding value for persistency and further optimisation of the runtime for the solution of the system is intended.

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Table 1. Heritabilities (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlations from reduced CF for first ($_F$), second ($_S$) and later ($_L$) lactation milk (M), fat (F) and protein (P) test-day yields for a sample of days in milk (DIM).

	DIM	14	47	80	146	212	311	14	47	80	146	212	311	14	47	80	146	212	311
				M_F						M_S						M_L			
	14	.25	.91	.87	.77	.65	.40	.95	.84	.78	.66	.51	.25	.92	.83	.77	.63	.50	.30
	47	.66	.27	.99	.93	.83	.63	.85	.93	.91	.82	.66	.38	.92	.93	.90	.80	.66	.38
M_F	80	.61	.74	.28	.97	.90	.74	.81	.92	.93	.87	.75	.48	.88	.93	.93	.86	.74	.47
	146	.50	.64	.69	.28	.98	.88	.70	.87	.91	.93	.86	.66	.78	.89	.93	.92	.84	.60
	212	.41	.53	.61	.69	.27	.96	.57	.78	.85	.93	.92	.78	.65	.82	.88	.93	.89	.68
	311	.34	.42	.47	.55	.61	.20	.32	.60	.72	.87	.92	.85	.43	.66	.76	.87	.89	.71
	14	.44	.39	.39	.35	.29	.15	.22	.86	.79	.65	.48	.21	.95	.84	.77	.61	.44	.19
	47	.36	.41	.43	.43	.39	.27	.68	.22	.98	.88	.71	.40	.97	.99	.97	.86	.70	.36
M_S	80	.35	.42	.45	.46	.43	.33	.64	.76	.23	.95	.82	.54	.91	.99	.99	.94	.81	.49
	146	.33	.40	.44	.48	.48	.41	.55	.66	.70	.25	.96	.78	.76	.90	.96	.99	.95	.70
	212	.27	.35	.39	.45	.47	.43	.40	.51	.58	.67	.25	.92	.57	.74	.85	.96	.98	.81
	311	.13	.22	.26	.32	.35	.35	.14	.25	.34	.50	.62	.23	.25	.44	.58	.79	.90	.86
	14	.31	.33	.33	.33	.31	.27	.43	.45	.44	.39	.30	.12	.16	.94	.89	.73	.56	.24
	47	.32	.41	.42	.39	.36	.29	.40	.46	.46	.42	.35	.20	.63	.22	.98	.89	.74	.44
M_L	80	.32	.41	.43	.42	.39	.33	.39	.46	.47	.46	.40	.27	.59	.75	.23	.95	.84	.55
	146	.29	.38	.41	.43	.43	.39	.35	.43	.46	.50	.48	.38	.49	.64	.69	.26	.96	.74
	212	.24	.32	.36	.40	.42	.41	.26	.35	.40	.48	.50	.45	.38	.51	.58	.67	.26	.88
	311	.12	.20	.24	.29	.33	.35	.08	.18	.25	.36	.43	.46	.21	.33	.39	.50	.58	.25
				F_F						F_S						F_L			
	14	.29	.88	.76	.64	.54	.39	.94	.79	.66	.53	.43	.28	.86	.81	.67	.53	.40	.21
	47	.54	.20	.98	.90	.81	.65	.90	.97	.90	.78	.64	.42	.79	.97	.90	.76	.60	.35
F_F	80	.45	.60	.19	.97	.89	.77	.79	.97	.95	.86	.73	.51	.67	.96	.95	.84	.69	.44
	146	.39	.50	.52	.18	.98	.90	.64	.90	.95	.93	.85	.68	.51	.89	.95	.92	.82	.59
	212	.32	.38	.42	.50	.16	.97	.49	.80	.89	.94	.92	.80	.36	.79	.90	.94	.89	.70
	311	.22	.29	.35	.46	.52	.14	.30	.65	.79	.91	.94	.88	.17	.64	.80	.92	.93	.78
	14	.38	.31	.28	.26	.23	.16	.21	.84	.68	.50	.35	.15	.90	.84	.68	.47	.30	.07
	47	.28	.31	.32	.32	.30	.25	.54	.15	.96	.85	.69	.44	.72	.99	.96	.82	.65	.40
F_S	80	.25	.31	.33	.35	.34	.29	.44	.64	.16	.95	.83	.61	.54	.95	.99	.93	.80	.57
	146	.24	.30	.34	.39	.39	.35	.36	.50	.54	.18	.96	.82	.33	.83	.96	.99	.94	.75
	212	.21	.27	.30	.37	.39	.36	.26	.34	.41	.52	.20	.94	.18	.67	.85	.98	.98	.83
	311	.14	.19	.24	.31	.35	.34	.12	.23	.31	.46	.53	.23	.02	.43	.64	.86	.93	.83
	14	.32	.27	.24	.23	.19	.14	.33	.28	.25	.22	.16	.05	.18	.75	.54	.32	.16	-.04
	47	.26	.29	.30	.30	.27	.22	.28	.33	.33	.31	.25	.16	.53	.13	.95	.81	.65	.42
F_L	80	.23	.29	.30	.32	.30	.25	.26	.33	.35	.35	.31	.24	.42	.64	.14	.94	.83	.62
	146	.21	.27	.29	.33	.33	.30	.23	.31	.35	.41	.41	.36	.32	.49	.53	.18	.97	.80
	212	.17	.22	.25	.30	.32	.30	.17	.25	.30	.40	.43	.41	.23	.34	.41	.52	.19	.91
	311	.11	.16	.19	.24	.27	.26	.05	.15	.22	.33	.38	.39	.14	.27	.34	.45	.51	.22
				P_F						P_S						P_L			
	14	.19	.92	.85	.77	.68	.43	.95	.88	.79	.69	.55	.21	.93	.87	.78	.66	.51	.19
	47	.56	.18	.98	.92	.81	.62	.90	.95	.90	.79	.64	.32	.95	.94	.87	.76	.62	.28
P_F	80	.49	.64	.18	.96	.88	.73	.84	.94	.92	.84	.71	.43	.91	.94	.90	.81	.69	.37
	146	.40	.54	.61	.19	.98	.88	.77	.91	.93	.91	.83	.62	.84	.92	.92	.89	.81	.52
	212	.34	.43	.51	.63	.18	.95	.68	.84	.89	.92	.89	.74	.75	.85	.89	.91	.86	.61
	311	.26	.33	.38	.47	.56	.12	.44	.67	.77	.85	.87	.83	.53	.69	.77	.86	.86	.68
	14	.36	.35	.35	.35	.33	.24	.17	.89	.78	.69	.57	.26	.88	.87	.80	.66	.51	.20
	47	.31	.34	.36	.39	.38	.30	.58	.15	.98	.89	.75	.46	.95	.99	.95	.86	.72	.37
P_S	80	.29	.34	.37	.41	.40	.32	.54	.65	.16	.95	.84	.60	.90	.98	.98	.93	.82	.51
	146	.29	.33	.37	.43	.44	.37	.50	.59	.63	.18	.96	.80	.78	.92	.96	.99	.95	.72
	212	.25	.29	.33	.39	.42	.38	.42	.47	.52	.63	.20	.92	.62	.79	.88	.98	.99	.82
	311	.08	.14	.19	.26	.30	.33	.15	.23	.32	.47	.60	.21	.32	.51	.64	.82	.91	.83
	14	.25	.26	.26	.28	.27	.20	.38	.39	.39	.38	.34	.19	.13	.91	.83	.73	.59	.18
	47	.27	.29	.31	.34	.33	.24	.39	.42	.43	.41	.36	.23	.54	.14	.98	.90	.77	.49
P_L	80	.27	.30	.33	.36	.36	.27	.37	.42	.43	.43	.39	.28	.47	.63	.15	.96	.87	.63
	146	.27	.30	.33	.39	.40	.31	.34	.40	.42	.47	.46	.38	.42	.56	.62	.19	.97	.77
	212	.24	.27	.30	.37	.39	.31	.26	.33	.38	.46	.48	.44	.36	.45	.52	.63	.20	.87
	311	.13	.16	.19	.27	.30	.25	.07	.17	.24	.34	.40	.44	.20	.30	.37	.49	.58	.21

Table 2. Standard deviations (kg) of estimated breeding values of bulls from reduced rank random regression test-day model (TDM) and corresponding breeding values obtained from the current multiple trait lactation model in Germany (LM-DEU) and Austria (LM-AUT). Standard deviations are for bulls born 1993-1994 with a minimum of 50 daughters in TDM evaluation.

		Simmental				Brown Swiss			
		# bulls	First	Second	Later	# bulls	First	Second	Later
milk	LM- DEU	n=946	421	428	390	n=179	412	448	407
	TDM	n=946	388	431	461	n=179	348	424	449
	LM-AUT	n=216	406	415	403	n=63	271	317	277
	TDM	n=216	442	476	511	n=63	340	357	384
fat	LM- DEU	n=946	17.1	18.1	17.2	n=179	16.1	16.9	15.6
	TDM	n=946	13.7	17.1	17.7	n=179	12.5	16.0	16.7
	LM-AUT	n=216	16.5	17.1	16.9	n=63	12.9	14.4	13.7
	TDM	n=216	15.1	17.8	18.3	n=63	11.8	13.5	13.8
protein	LM- DEU	n=946	12.3	13.4	12.5	n=179	12.7	14.7	13.6
	TDM	n=946	10.7	12.9	13.6	n=179	10.8	13.5	13.9
	LM-AUT	n=216	10.9	11.6	11.3	n=63	7.9	8.7	7.8
	TDM	n=216	12.5	14.6	15.4	n=63	9.3	10.3	10.8

Table 3. Correlations between estimated breeding values from reduced rank random regression test-day model (TDM) and corresponding breeding values obtained from the current multiple trait lactation model in Germany (LM-DEU) and Austria (LM-AUT). Correlations ($r_{TDM,LM}$) are for bulls born 1993-1994 with a minimum of 50 daughters in TDM evaluation and for cows born between 1990 and 1993 separately for first, second and later lactations.

			Simmental				Brown Swiss		
			First	Second	Later		First	Second	Later
BULLS									
milk	$r_{TDM,LM-DEU}$	n=946	0.96	0.94	0.92	n=179	0.96	0.95	0.92
	$r_{TDM,LM-AUT}$	n=216	0.93	0.93	0.91	n= 63	0.92	0.89	0.87
fat	$r_{TDM,LM-DEU}$	n=946	0.95	0.94	0.93	n=179	0.96	0.94	0.92
	$r_{TDM,LM-AUT}$	n=216	0.91	0.92	0.91	n= 63	0.87	0.84	0.81
protein	$r_{TDM,LM-DEU}$	n=946	0.94	0.92	0.90	n=179	0.95	0.94	0.89
	$r_{TDM,LM-AUT}$	n=216	0.87	0.88	0.85	n= 63	0.91	0.88	0.87
COWS									
milk	$r_{TDM,LM-DEU}$	n=1186643	0.86	0.86	0.85	n=234391	0.87	0.86	0.86
	$r_{TDM,LM-AUT}$	n= 229135	0.84	0.82	0.82	n= 68474	0.79	0.78	0.79
fat	$r_{TDM,LM-DEU}$	n=1186643	0.84	0.85	0.86	n=234391	0.85	0.85	0.85
	$r_{TDM,LM-AUT}$	n= 229135	0.79	0.82	0.83	n= 68474	0.74	0.76	0.76
protein	$r_{TDM,LM-DEU}$	n=1186643	0.83	0.86	0.86	n=234391	0.86	0.88	0.87
	$r_{TDM,LM-AUT}$	n= 229135	0.75	0.78	0.79	n= 68474	0.74	0.78	0.80