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Genetic parameters for testday models

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Introduction

Traditionally, 305-day lactation yields have been used for selection on production traits in dairy cattle. Therefore evaluation models worldwide almost exclusively are based on using 305-day records. In recent years, more attention has been paid to use records from single testdays, e.g. in MOET-scheme selection programmes in order to be able to select animals earlier and by this way reducing the generation interval. Furthermore, some breeders feel that the rigid 305-day system does not adequately work for cows with different lactation lengths, especially if these are long and contents of fat and protein is considered.

Many authors have estimated genetic parameters for testday yields (e.g. Danell, 1982; Pander et al., 1992). They conclude that heritability estimates for the mid-part of the lactation are close to estimates for the entire lactation although considerably lower at the beginning and the end of the lactation. Also, genetic correlations between testday records in mid-lactation and 305-day records seem to be high, i.e. > .80. Some authors have used standardized intervals (mostly standardized to 30-day intervals) instead of testday yields to account for variable length of intervals between testdays (e.g. Wilmink, 1986; Meyer et al., 1989). Estimates of heritabilities for yield traits do not change much when using standardized intervals, however, a substantial increase in heritability can be found for fat and protein contents and the genetic correlations for mid-lactation intervals with 305-day yield appear to be close to unity.

Much work has been done in modeling the shape of the lactation curve, for an older but extensive review see Masselin et al. (1987), later work can be found in Grossman and Koops (1988), Elston et al. (1989), and Stanton et al. (1992). Most of this work has been done triggered by the classical paper of Wood (1967) in an attempt to improve upon his model. Genetic parameters for factors describing the shape of the lactation curve have been estimated, a practical implementation into selection programmes, however, is unknown.

Up to recently, the two approaches of dealing with testday data, estimation of parameters for single testdays and suggestions to use testday records for selection programmes, and

modeling the shape of the lactation curve have not been brought into one perspective. However, Ptak and Schaeffer (1993) suggested a repeatability animal model in which single testday records are taken as repeated measurements and factors to model the curve of the lactation are included. The factors used were derived from work of Ali and Schaeffer (1987) who suggested a regression model to describe the curve of the lactation and demonstrated the advantage over other models, including Wood's model.

Ptak and Schaeffer (1993) emphasize that it is possible to more precisely model dairy records when applying a testday model instead of traditional 305-day model. Also, extension of records can be avoided, cows could be grouped into different contemporary groups within herd according to their stage of lactation like it is actually done on many farms, and possibly less testdays than currently recorded could be used thus reducing the expense of at least storing 10 or more testday records per cow and lactation.

For Germany not much and mostly outdated literature on studies analyzing testday records can be found. Therefore, a preliminary analysis (Kahtenbrink und Swalve, 1993) using a small (3665 cows) data set was undertaken to assess the accordance of parameter estimates from other studies with parameters estimated from recent german data. This analysis confirmed the importance of mid-lactation testdays and standardized intervals. For yield traits heritabilities in the order of those for 305-day lactation yields were estimated for testday 2 to 6 (for standardized 30-day intervals: all intervals between 31 and 210 days). For fat and protein contents heritabilities were highest for testdays 6 to 8 (for standardized intervals: all intervals between 91 and 270 days) although slightly less than those obtained for 305-day records. Genetic correlations of mid-lactation records with 305-day records were essentially unity.

Aim of the present study was to estimate variance components for testday yields using more data than in the study of Kahtenbrink and Swalve (1993) and at the same time consider the effect of the herd structure in Germany which usually is characterized by small herds. Furthermore, based on the findings of the preliminary study and on the estimation of variance components for a larger data set, the aim was also to estimate variance components using a testday model as suggested by Ptak and Schaeffer (1993).

Material and Methods

Data was supplied by RLN (Agricultural Computing Center), Verden, and covered two regions from northern Germany, one coastal region where herdsizes commonly are large by german standards and one inland region with size of herds more typical for western Germany. All calvings were from years 1985 to 1991. In the german milk recording scheme all testday records are stored on an "as recorded" basis grouped by years. In the RLN scheme these records even cover years in an overlapping fashion so that firstly single calvings and subsequent testdays had to be extracted to form lactation records. Table 1 displays the editing steps and the structure of the final data sets, henceforth denoted by Region 1 and Region 2. Only first lactations with at least 8 testdays were used. Traits analyzed were: milk yield, fat yield, protein yield, fat contents, and protein contents. Further edits were applied in two steps: Firstly records were checked for reasonable intervals between calving and first testday (4 - 45 days) and between later testdays (14 - 70 days). Production was limited to ranges of 2 - 70 kg for milk yield, 2 - 7% for fat contents, and 1.5 - 5% for protein contents; age of calving was restricted to 610 - 1280 days (20 - 42 months). Secondly, it was attempted to obtain a structure of the data suitable for a genetic analysis. Cows were required to descend from an A.I. sire. Herd sizes (across years) were restricted differently for the two regions: For Region 1 the lower limit was 30 first lactation records, for Region 2 60 records. This yielded two data sets with 13,026 and 15,756 cows for Region 1 and Region 2, respectively.

Variance components were estimated using DFREML 2.0 (Meyer, 1991) applying animal models throughout the analysis. Pedigrees were completed using the RLN sire file for the male side thus tracing back most bulls to ancestors from the 1960's. For females, pedigree information had to be taken from the testday record files and only allowed for the inclusion of one additional dam generation.

The definition of models was based on the preliminary analysis by Kahtenbrink and Swalve (1993) and can be summarized as follows:

Model I : For 305-day lactation records and single testday records

$$y_{ijk} = HYS_i + bX + a_j + e_{ijk}$$

where

y_{ijk} = 305-day record, or record from a single testday

HYS_{ijk} = effect of herd-year season of calving - Region 2 only; for Region 1 this effect was split into a herd effect and a year-season effect neglecting the interaction

bX = covariates:
- X_1 = age of calving
- X_2 = days in milk at first testday (DIM01)

a_j = animal's additive genetic effect

e_{ijk} = residual effect

Model II : Simple testday-repeatability model

$$y_{ijk} = HYS_i + bX + a_j + pe_j + e_{ijk}$$

where

y_{ijk} = record from a single testday (or single standardized 30-day interval)

bX = covariates:
- X_1 = age of calving
- X_2 = DIM/c
- where DIM = days in milk and c is a constant, set to 305 (as in Ptak and Schaeffer (1993)
- $X_3 = (DIM/c)^2$
- $X_4 = \ln(c/DIM)$
- $X_5 = (\ln(c/DIM))^2$

pe_j = effect of permanent environment of the cow during lactation

Other terms as defined previously

This model is similar to model TY1 of Ptak and Schaeffer (1993), except that the regression coefficients are not nested within age-season.

Model III : Testday-repeatability model with herd-testday effect (applied to Region 2 only)

$$y_{ijk} = HTD_i + bX + a_j + pe_j + e_{ijk}$$

where

HTD_i = effect of herd-testday

Other terms as defined previously

This model is similar to model TY3 of Ptak and Schaeffer (1993) with the exceptions as explained above.

Under model III the number of fixed effet levels obviously increases drastically, as can be seen from Table 1. Due to limits in computing facilities the data set Region 2 had to be cut down to one third of it's original size since otherwise approximately 20,000 levels for HTD would have been coded. Extraction of a manageable data set was done by limiting the resulting set to big herds only (≥ 800 testday records across years) which yielded a set of 4774 cows with a total of 47,289 records in 4248 herd-testday subclasses.

Results and Discussion

Table 2 displays raw means and standard deviations for 305-day production traits and days in milk (DIM) for successive testdays. With the exception of a slightly higher fat percentage in Region 2 the two data sets appear to be very similar with respect to these statistics.

Estimates of heritabilities for 305-day records are given in Table 3. Estimates for Region 2 are slightly higher than for Region 2 which may be attributed to the improved model that could be used. With the exception of the estimates for yield of fat and protein for Region 1 which are somewhat low, estimates are in good agreement with other studies on parameters for northern Germany (e.g. Kahtenbrink and Swalve, 1993; Dodenhoff and Swalve, 1993).

Estimates of heritabilities for single testday records are shown in Table 4. Again, estimates for fat and protein yield are rather low. Estimates for Region 2 appear to be slightly higher than those for Region 1, this is especially true for estimates for fat and protein yield in the second half of the lactation. For milk yield in Region 2 estimates are of similar size as those for 305-day records for mid-lactation testdays. Fat and protein contents yield relatively high estimates for the second half of the lactation. Heritabilities for testday 1 generally are low which should be considered in selection programmes that use a single first testday record for early selection.

The simple testday-repeatability model, model II, produced estimates as given in Table 5. The first part of Table 5 presents estimates obtained when 8 testday records were used for each cow whereas for a second analysis all available testdays for each cow were used. For yield traits estimates of heritabilities are in the range or close to the values for 305-day records. However, estimates for fat and protein contents are rather low. This changes when the analysis is restricted to four testdays only. Corresponding to the results from Table 4, for yield traits testdays 3 to 6 were used whereas for fat and protein contents a shift towards later testdays seemed to be reasonable, thus considering testdays 4 to 7. It may be assumed that the regression model proposed by Ali and Schaeffer (1987) may not adequately fit for fat and protein contents but is improved if only later testdays are used.

In Table 6, estimates are shown that resulted from using model II for records defined as average daily yields in 30-day intervals. Thus for each cow the values for DIM used in the regression factors of model II were identical, e.g. DIM = 15 for interval 1-30 days, DIM = 45 for interval 31-60 days, and so on. The regression factors X_2 to X_5 therefore each were estimated only from 8 points. Due to general limitations in computing time this type of analysis could only be carried out for Region 1. Estimates for yield traits are similar to those in Table 5 whereas a substantial increase is observed for fat and protein contents. This is in agreement with findings of Kahtenbrink and Swalve (1993) when analyzing single records. Compared to the estimates for single testdays the estimates of heritabilities for records of standardized intervals substantially increased. It can only be speculated what would happen when the approach documented in the bottom part of Table 5 (using four mid-lactation testdays only) would be applied to records of standardized intervals. This will be a next step in the ongoing project.

Finally, Table 7 displays results obtained under model III, i.e. using herd - testdays as a definition of contemporary groups instead of herd - year - seasons. Unfortunately the results given here can not be compared directly to those in Table 5 since only part of the data of the original data set Region 2 could be used. Heritability estimates appear to be slightly higher than those in the first part of Table 5 for Region 2. For all traits the estimate of the residual variance was reduced compared to results from model II which lead to slightly increased heritabilities. However, it has to be examined if this is due to the reduction of the data set or due to a clear superiority of model III over model II. The problem of analyzing the entire data set is largely a matter of core storage requirements for the DFREML program under the installation in Göttingen but should be solved in the near future.

Conclusions

Future research on testday models appears to be very justified since opportunities for substantial improvements of models are plentiful. However, as Ptak and Schaeffer put it, "much work is needed to perfect models".

Future work should concentrate on the following subjects:

1. Reevaluation of the many models describing the shape of the lactation curve with respect to their use in testday models

2. Is there a need for models for fat and protein contents?

3. Importance of using standardized interval records instead of raw testdays

4. Combining all lactations in testday models

5. Which testdays or intervals are most important so that reduced data sets can be used

6. Multi-trait testday models

7. Incorporate the effect of pregnancy

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Table 1: Editing of the data and data structure

	Region 1	Region 2
No. of yearly records[1]	423,570	643,174
No. of lactations (1-4; ≥ 1 testdays)	379,645	543,649
No. of 1. lactations (≥ 8 testdays)	76,521	112,868
No. of 1. lactations (≥ 8 testdays, fully edited[2]) = final data set	13,026	15,756
No. of herds in final data set	315	215
No. of sires in final data set	638	783
No. of Year-Seasons (Region 1)	13	
No. of Herd-Year-Seasons (Region 2)		2660
No. of herd-testdays (Region 2, reduced data set of 4774 lactations)		4248
Average no. of testdays per cow	9.89	9.87

[1] Testday records are stored on a yearly basis with overlapping years by RLN

[2] Edits on herdsize (≥ 30 across years for region 1; ≥ 60 across years for region 2, further edits on A.I. sires only, length of intervals between calving and 1. testday and between subsequent testdays, production, age of calving)

Table 2: Means and standard deviations of 305-day first lactation production and average days in milk at successive testdays

Trait	Region 1		Region 2	
	mean	s.d.	mean	s.d.
Production traits				
Milk (kg)	5998	1045	6003	1007
Fat (kg)	248	46	251	44
Protein (kg)	198	35	199	33
Fat (%)	4.14	0.40	4.20	0.40
Protein (%)	3.31	0.21	3.32	0.19
Average days in milk at successive testdays (TD's)				
TD 01	19.78	9.39	19.50	9.39
TD 02	50.78	12.14	50.44	11.93
TD 03	82.37	13.69	81.70	13.32
TD 04	113.99	15.49	112.87	14.87
TD 05	147.06	16.70	145.26	15.68
TD 06	180.48	18.18	177.84	17.05
TD 07	215.11	19.71	211.20	19.16
TD 08	249.77	20.26	245.41	20.20
TD 09[*]	282.32	19.43	277.59	19.78
TD 10[*]	310.82	19.39	305.86	19.60
TD 11[*]	347.61	13.13	344.37	14.90
TD 12[*]	378.53	9.48	377.22	9.97
TD 13[*]	389.97	4.83	389.47	3.47

[*] TD01 - TD08 recorded for all cows in each data set (region)
No. of records for later testdays:
Region 1: TD09 - 11,661; TD10 - 7969; TD11 - 3661; TD12 - 1241; TD13 - 34.
Region 2: TD09 - 14,340; TD10 - 9849; TD11 - 4013; TD12 - 1208; TD13 - 36.

Table 3: Estimates of heritabilities for five production traits (305-day first lactation) by region (Model I)

Trait	Region 1		Region 2	
	h^2	s.e.	h^2	s.e.
Milk (kg)	.36	.031	.39	.031
Fat (kg)	.30	.030	.32	.032
Protein (kg)	.27	.029	.30	.031
Fat (%)	.61	.030	.67	.029
Protein (%)	.60	.030	.60	.030

Table 4: Estimates of heritabilities for testdays 1 to 8 for five dairy production traits by region (s.e. of h^2: .023 - .033; model I)

No. of Testday	Trait				
	Milk (kg)	Fat (kg)	Protein (kg)	Fat (%)	Protein (%)
Region 1					
1	.19	.18	.12	.19	.20
2	.19	.14	.13	.22	.26
3	.23	.18	.15	.27	.35
4	.25	.17	.16	.36	.40
5	.26	.20	.18	.41	.37
6	.27	.15	.17	.37	.41
7	.23	.14	.17	.38	.36
8	.21	.14	.15	.35	.33
Region 2					
1	.18	.16	.12	.19	.20
2	.24	.12	.17	.25	.32
3	.28	.14	.16	.36	.37
4	.33	.16	.19	.44	.38
5	.33	.18	.21	.41	.41
6	.36	.23	.21	.46	.34
7	.31	.21	.22	.45	.38
8	.25	.20	.17	.41	.35

Table 5: Estimates of heritabilities (h^2) and effects of the permanent environment of cows in first lactation (p.e.) using a testday - repeatability model (Model II) for five dairy production traits by region.
(First part: maximum of 8 testdays per cow; second part: as many testdays per cow as available; third part: only 4 testdays used, TD3 - TD6 for yield traits, TD4 - TD7 for fat and protein contents)

Trait	Region 1		Region 2	
	h^2	p.e.	h^2	p.e.
Maximum of 8 testdays per cow used				
Milk (kg)	.33	.44	.38	.39
Fat (kg)	.26	.46	.28	.44
Protein (kg)	.30	.41	.28	.45
Fat (%)	.24	.45	.22	.51
Protein (%)	.25	.47	.23	.50
As many testdays per cows used as available				
Milk (kg)	.31	.41	.33	.42
Fat (kg)	.24	.46	.26	.45
Protein (kg)	.26	.43	.26	.45
Fat (%)	.24	.44	.22	.50
Protein (%)	.24	.43	.23	.45
Maximum of 4 testdays used				
Milk (kg)	.38	.44	.41	.44
Fat (kg)	.32	.44	.35	.41
Protein (kg)	.36	.41	.37	.41
Fat (%)	.35	.42	.40	.34
Protein (%)	.34	.42	.35	.42

Table 6: Estimates of heritabilities (h^2) and effects of the permanent environment of cows in first lactation (p.e.) using a testday - repeatability model on testday records standardized to 30-day intervals for five dairy production traits. (model II)
- Region 1 -

Trait	h^2	p.e.
Milk (kg)	.34	.50
Fat (kg)	.30	.47
Protein (kg)	.27	.54
Fat (%)	.39	.27
Protein (%)	.34	.39

Table 7: Estimates of heritabilities (h^2) and effects of the permanent environment of cows in first lactation (p.e.) using a testday - repeatability model with contemporary groups defined as testdays within herd for five dairy production traits. (model III)
- Region 2 -

Trait	h^2	p.e.
Milk (kg)	.38	.45
Fat (kg)	.32	.42
Protein (kg)	.36	.42
Fat (%)	.32	.39
Protein (%)	.32	.40