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Modelling of the lactation curve as a sub-model in the evaluation of test day records

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Introduction

Attempts to model the shape of the lactation curve of the dairy cow have been numerous (e.g. see review by Masselin et al., 1987). The work by Wood (1967), amongst others, is widely known.

Recently, attention has been drawn to make use of test day records in the evaluation of dairy cattle instead of basing evaluations on complete or 305-day lactation records. Two strategies (see review by Swalve, 1995) have been proposed: Precorrection of test day records and combining the corrected records into lactational records (Two-step method) and repeatability animal models in which test day records within a lactation are modelled as repeated records (One-step method) and the shape of the lactation curve is accounted for by an appropriate sub-model, some form of a regression of yield on a specific test day on days in milk. The latter strategy has been proposed by Ptak and Schaeffer (1993), their model included a sub-model as presented by Ali and Schaeffer (1987). Schaeffer and Dekkers (1994) suggested to apply the regression within cow in the form of a „random regression" to account for differences of the shape of the lactation curve individually. Aim of the present study was to compare models describing the lactation curve.

Material and Methods

Data consisted of yield of milk recorded daily on the experimental farm „Karkendamm" of the University of Kiel and covered a total of 322 lactations with more than 250 days in milk from 179 cows in parities one to ten. The structure of the data is given in Table 1. In subsequent tables only results for first parities will be reported for sake of brevity. Contents of fat and protein was recorded in weekly intervals.

For the present study, the original data was used to mimick various sampling intervals. For milk yield, five different sampling intervals were used: M10 and M24 using 30-day intervals with the first sample taken on day 10 and day 24, respectively; and BM10 / BM24 using the same days for the first test but increasing the interval to 60 days (bimonthly). As an extensive scheme sampling was done at days 10, 66 and (LL-30), where LL denotes length of lactation. The scheme was denoted as 3POINTS. For yield and contents of fat and protein the schemes 4W and 8W with intervals of 28 and 56 days, respectively were defined.

A total of 14 models, partly based on earlier work by Wood (1967), Kanderkar (1956) and Wilmink (1987) were compared of which results for 8 models shall be reported here. The models are defined as follows:

W:	$y_t=at^be^{ct}$	(Wood, 1967)
LM:	$y_t=a_1+a_2t+a_3\exp(-0.5(\lg(t)-1)/\sigma)^2)/t$ ($\sigma=0.6$)	(Log model)
MIL1:	$y_t=a_1+a_2\mathrm{sqrt}(t)+a_3\ln(t)$	(Mixed Log model I)
MIL3:	$y_t=a_1+a_2\mathrm{sqrt}(t)+a_3\ln(t)+a_4t^4$	(Mixed Log model III)
AS:	$y_t=a_1+a_2(t/c)+a_3(t/c)^2+a_4\ln(c/t)+a_5(\ln(c/t))^2$	(Ali and Schaeffer, 1987)
MW2:	$y_t=a_1+a_2t+a_3\sin(t/100)t^2+a_4\sin(t/100)t^3+a_5e^{-0.055t}$	(Modified Wilmink II)
MK1:	$y_t=a_1+a_2t+a_3t^2+a_4t^3+a_5\ln(t)$	(Modified Khanderkar I)
P:	$y_t=a_1+a_2t+a_3t^2+a_4t^3+a_5t^4+a_6t^5+a_7t^6$	(Polynomial model)

The correlation between actual yield and yield estimated applying a model and the mean absolute error comparing actual and estimated yield were chosen as criteria for comparison, henceforth denoted by criterion 1 and 2, respectively.

Results and Discussion

The results for milk yield are given in Table 2, those for fat and protein yield and contents in Table 3. Considerable differences exist between models, especially when criterion 2 is used for comparison. It is very clear that contents of fat and protein is far more difficult to predict than yield of milk, fat or protein. In general, extended intervals result in a poorer fit but exceptions exist. Among the models, the best models in each sampling scenario are marked. Two different markings were used to point to the best model overall and to the best model with only three parameters to estimate since a restriction of the number of parameters may be necessary for the use in evaluation models. For milk yield the models MW2 and MIL1 seem to give the best fit, for fat and protein traits the situation is more complicated but some tendency towards a superiority of models LM and MK1 is visible.

Conclusion

Considerable differences exist between models which should also be present when models like the ones presented are used as sub-models in one-step test day models. However, these differences may only be of significance when the parameters for the sub-models are allowed to differ among sub-groups of the data if not applied individually.

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Table 1. Data Structure

Parities	NL[1]	NC[2]	LL[3](days)		Milk Production(kg)		Peak Yield	
			Mean	Std Dev[4]	Mean	Std Dev	Day	Yield(kg)
1	98	98	339	73	6178	1741	66	28
2	67	25	320	44	6905	1382	40	35
≥3	157	56	332	58	7827	1712	46	40
Total	322	179	332	61	7133	1805	51	35

[1]Number of Lactations [2]Number of Cows [4]Length of Lactation [3]Standard Deviation

Table 2. Goodness of fit of 8 models describing the lactation curve by sampling scenario for milk yield

Sampling scenario	Cri-terion	MODELS							
		W	LM	MIL1	MIL3	AS	MW2	MK1	P
M10	1	0.862	0.865	**0.868**	0.881	0.869	**0.893**	0.891	0.877
	2	1.486	1.481	**1.465**	1.314	1.325	**1.222**	1.248	1.302
M24	1	0.846	0.822	**0.856**	0.855	0.677	**0.865**	0.824	0.832
	2	1.534	1.606	**1.490**	1.382	1.936	**1.317**	1.439	1.500
BM10	1	0.854	0.863	**0.864**	0.840	0.775	**0.856**	0.837	0.851
	2	1.639	1.595	**1.586**	1.536	2.091	1.549	1.649	**1.531**
BM24	1	0.824	0.793	**0.832**	0.816	0.862	**0.877**	0.876	0.867
	2	1.626	1.708	**1.589**	1.578	1.433	**1.387**	1.390	1.434
3POINTS	1	0.844	**0.858**	0.854					
	2	1.996	**1.930**	1.968					

Note 1. ?.??? : the best fitting quality of all models
2. ?.??? : the best fitting quality of the models that have only three parameters

Table 3. Goodness of fit of 8 models describing the lactation curve by sampling scenario for fat and protein yield and contents

Sampling scenario	Criterion	MODELS							
		W	LM	MIL1	MIL3	AS	MW2	MK1	P
Fat Yield									
4W	1	0.769	0.765	**0.772**	0.788	0.784	0.789	**0.796**	0.779
	2	0.074	**0.072**	0.072	0.069	0.068	0.067	**0.067**	0.068
8W	1	0.755	**0.756**	0.758	0.756	0.621	0.716	0.702	0.735
	2	0.078	**0.076**	0.077	0.076	0.105	0.082	0.085	0.078
Fat Content									
4W	1	0.562	**0.591**	0.589	0.647	0.646	0.659	**0.665**	0.641
	2	0.325	**0.314**	0.317	0.291	0.288	0.286	**0.283**	0.298
8W	1	0.534	**0.571**	0.559	**0.582**	0.485	0.571	0.561	0.577
	2	0.343	**0.334**	0.338	**0.326**	0.405	0.332	0.343	0.329
Protein Yield									
4W	1	**0.824**	0.807	0.815	0.854	0.847	**0.859**	0.856	0.854
	2	0.054	0.055	**0.054**	0.048	0.047	0.046	0.046	**0.045**
8W	1	**0.805**	0.795	0.798	**0.830**	0.668	0.772	0.763	0.823
	2	0.058	**0.058**	0.058	0.054	0.074	0.056	0.058	**0.052**
Protein Content									
4W	1	0.594	**0.619**	0.619	0.690	0.738	0.730	**0.763**	0.745
	2	0.144	**0.138**	0.139	0.122	0.112	0.116	**0.107**	0.110
8W	1	0.562	**0.595**	0.586	0.639	0.620	0.657	**0.695**	0.659
	2	0.148	**0.142**	0.143	0.131	0.162	0.137	**0.130**	0.133

Note 1. ?.??? : **the best fitting quality of all models**
2. ?.??? : **the best fittimg qaulity of the models that have only three parameters**