Accounting for the Effect of Pregnancy in the Canadian Test Day Model

J. Bohmanova[1], F. Miglior[23], J. Jamrozik[1], L.R. Schaeffer[1] and S. Loker[1]
[1]*CGIL, University of Guelph, Guelph, ON*
[2]*Agriculture and Agri-Food Canada, Sherbrooke, QC*
[3]*Canadian Dairy Network, Guelph, ON*

Introduction

Pregnancy has been reported to have a negative effect on milk yield of dairy cows due to hormonal changes, causing regression of the mammary gland (Akers, 2006), and nutrient requirements of the fetus, reducing available nutrients for milk production (Bell *et al.,* 1995). The effect of pregnancy is small at the beginning of gestation and becomes greater at later stages of gestation when growth and nutrient requirements of the fetus are larger. Significant effect of pregnancy on milk yield is usually observed from the 5th month of gestation onwards (Bormann *et al.,* 2002; Haile-Mariam *et al.,* 2003; Olori *et al.,* 1997; Roche, 2003).The current Canadian Test Day Model (**CTDM**) does not adjust for the effect of pregnancy and therefore breeding values of non-pregnant cows could be inflated.

The aim of this study was to identify the most appropriate model for accounting for the effect of pregnancy in the CTDM using test-day (**TD**) records up to 365 days in milk (**DIM**).

Material and Methods

Data

Data were 22,785,028 TD milk, fat and protein yield and SCS records of 2,752,844 Canadian Holstein heifers calved between 1988 and 2006. Only TD with DIM from 5 to 365-d were included. A truncated data set was created by eliminating 5 last years of data. The pedigree file contained 3,727,873 animals. The insemination data set containing 11,100,925 insemination records was used to determine cow's conception date of her second pregnancy. Since recording of artificial inseminations started in Canada in 1997, not all cows in this study had available breeding records.

A gestation length of 280-d was assumed (average gestation length of Holsteins). When a cow had a subsequent lactation but no breeding record, the conception date was set to the date 280-d prior to her second calving. For a cow with subsequent calving and insemination records located in the interval of 280±15-d prior her second calving, the conception date was set to the date of her last insemination record in this interval. For a cow without second calving but with available insemination records after her first calving, the conception date was set to her last available insemination record. A cow without subsequent calving and with no insemination record that completed her first lactation was assumed to be non-pregnant. Last available TD record was assumed to be the first day of dry period for a cow with lactation in progress. Considering average dry period of 60 days, the conception date was set to (280-60) days prior the last TD record. If such conception date occurred earlier than 125 DIM, it was set to 125-d after calving date.

Cows were grouped into 9 classes based on their days open (**DO**). The first class consisted of non-pregnant cows (**DO-NP**). Cows with DO shorter than 60-d were assigned to class **DO≤60**. Class **DO≤90** covered days 61 to 90, class **DO≤120** days 91 to 120, class **DO≤150** days 121 to 150, class **DO≤180** days 151 to 180, class **DO≤210** days 181 to 210, class **DO≤240** days 211 to 240. Cows with DO longer than 240-d were assigned to class **DO>240**.

TD records were divided into 13 stages of pregnancy classes defined as **W1** (days pregnant ≤ 10), **W2** (11≤ days pregnant ≤31), **W3** (32≤ days pregnant ≤52), **W4** (53≤ days pregnant ≤73), **W5** (74≤ days pregnant ≤94), **W6** (95≤ days pregnant ≤115), **W7** (116≤ days pregnant ≤136), **W8** (137≤ days pregnant ≤157), **W9** (158≤ days pregnant ≤178), **W10** (179≤ days pregnant ≤199), **W11** (200≤ days pregnant ≤220), **W12** (221≤ days pregnant ≤241), **W13** (days pregnant≥242).

Models

The TD records were analyzed by 4 multiple-trait random regression models. The effects common to all models (***common***) were:

$$common_{ijklr} = HTD_{ij} + \sum_{n=0}^{4} \alpha_{ikn} z_n(dim) + dim\_cl_l + \sum_{n=0}^{4} \beta_{irn} z_n(dim) + \sum_{n=0}^{4} \gamma_{irn} z_n(dim)$$

where HTD_{ij} was the jth herd-test-date fixed effect for trait i (TD milk, fat, protein yield and SCS), α_{ikn} was the nth fixed regression coefficient for the i^{th} trait specific to the n^{th} region-age-season class, dim_cl_l was the fixed effect of the lth DIM class (l=5,…..365), β_{irn} was the n^{th} random regression coefficient for the additive genetic effect of animal r, γ_{irn} was the n^{th} random regression coefficient for the permanent environmental effect of cow r, *z(dim)* was the vector of fixed and random regressions evaluated at DIM *dim*. Both fixed and random regressions were fitted with Legendre polynomials of order 4. All models used the same (co)variance components estimated previously by Bohmanova *et al.* (2008).

General model (G):

$$y_{ijklr} = common_{ijklr} + e_{ijklr},$$

where y_{ijklr} was the TD record for a trait *i*.

Days open model (DO):

$$y_{ijklrs} = common_{ijklr} + \sum_{n=0}^{4} \delta_{isn} z_n(dim) + e_{ijklrs},$$

where δ_{iln} was the n^{th} regression coefficient for the lth DO class, as defined earlier.

Stage of pregnancy model (SP)

$$y_{ijklrw} = common_{ijklr} + \upsilon_w + e_{ijklrw},$$

where υ_w is the effect of wth stage of pregnancy class, as defined earlier.

Stage of pregnancy x stage of lactation model (SPSL)

$$y_{ijklr0} = common_{ijklr} + \sum_{n=0}^{4} \phi_{ino} \omega_n(dp) + e_{ijklro},$$

where ϕ_{ino} the nth regression coefficient for the oth stage of lactation and ω_n is the nth covariate associated with days pregnant *dp*.

Model Comparisons

Models were compared by residual variance (**RV**), re-ranking of top 500 cows for milk yield EBV, and by an error of prediction (**ERP**) defined as:

$$ERP = \sqrt{\frac{\sum_{i=1}^{N} (ebv06_i - pa01_i)^2}{N}},$$

where *ebv06* was the EBV calculated from full data set, *pa01* was the average of animal's parent EBV calculated from a truncated data set where the last five years were removed, and *N* was the number of bulls with no daughters in the smaller data set and at least 25 daughters in full data set. For milk, fat and protein yield, *ebv06* was defined as 305-d EBV and for SCS as an average daily EBV. In order to account for differences in average of EBV between the two genetic evaluations, EBV from full data set were shifted by subtracting the average change in EBV estimated from the truncated dataset to EBV estimated from the full data set for a set of bulls whose average EBV was not expected to change. The adjustment was based on 1,865 bulls with at least 25 daughters in the full data set, no new daughters and no more than 10 new granddaughters between full and truncated data sets.

Results

As shown in Figure 1, the average milk yield curve of non-pregnant cows (DO-NP) is lower than curves of pregnant cows. This is not due to pregnancy but is caused by the fact that low yielding cows are culled after their first lactation and therefore are assigned to the non-pregnant group. Another problematic issue is that cows with shorter DO have lower milk yield than cows with longer DO. Therefore estimated milk yield curves by this model were lower for cows with short DO compared to cows with long DO. This suggests that the DO model will overestimate EBV of non-pregnant cows and cows with short DO.

Figure 1. Milk yield curves of 9 DO classes estimated by Model DO.

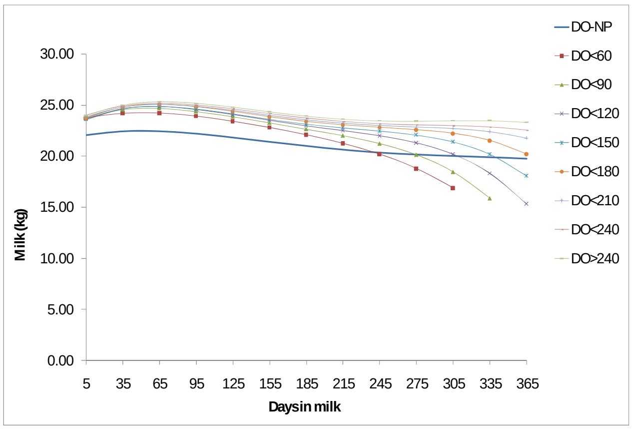
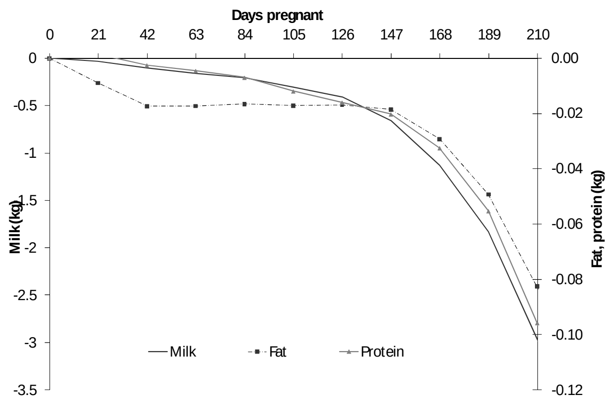


Figure 2 shows estimates of decline in milk, fat and protein yield for the 13 stages of pregnancy for model SP. Milk and protein yield slowly declined from conception till 4 months of pregnancy. The decline became steeper at later stages of pregnancy.

Figure 2. Decline of milk, fat and protein yield due to pregnancy estimated by Model SP.



Model SPSL considers differences in effect of pregnancy between cows conceived at different stages of lactation. Similarly as in model DO, non-pregnant cows had the lowest overall yield, and cows with longer DO had higher milk yield than cows with shorter DO (Figure3). No significant differences in rate of decline were found among different classes of stage of lactation, indicating that the effect of pregnancy was independent on stage of lactation when conception occurred.

Figure 3. Decline of milk due to pregnancy estimated by model SPSL for non-pregnant cows (NP), cows with days open shorter than 126 days (<=125d), days open between 126 and 245 days (126-245d) and with days open longer than 245 days (>=246d).

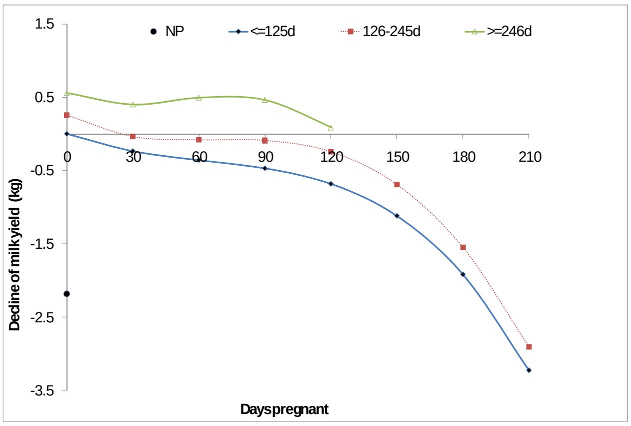


Table 1 shows percentages of non-pregnant cows in the top 500 for milk yield EBV. Both DO and SPSL had higher percentages of non-pregnant cows than model G, indicating that these two models overestimate EBV of non-pregnant cows.

As given in Table 2, all models with effect of pregnancy (DO, SP, SPSL) had lower residual variance than model G. The SPSL had the lowest RV.

Table 1. Number and % of non-pregnant and pregnant cows in the to 500 for milk yield EBV.

	G	DO	SP	SPSL
Non-pregnant	53 (11%)	86 (17%)	48 (10%)	101 (20%)
Pregnant	447 (89%)	414 (83%)	452 (90%)	399 (80%)

Model SP had the lowest ERP, followed by model DO. Surprisingly, the SPSL model had higher ERP than model G.

Table 2. Residual variance (RV) and Error of Prediction (ERP) for milk yield .

	G	DO	SP	SPSL
RV	3.22	3.17	3.19	3.16
ERP	1,789	1,577	1,488	2,018

Conclusions

Both DO and SPSL models had lower RV than SP model, however, these two models overestimated EBV of non-pregnant cows. This suggests that residual variance should not be used as the only criteria for model selection. Model SP is the best suitable model for adjusting for the effect of pregnancy in the Canadian Test Day Model.

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