The Effect of Pregnancy on Milk, Fat and Protein Yields of Canadian Ayrshire, Jersey, Brown Swiss and Guernsey breeds

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INTRODUCTION

Genetic evaluation of dairy cattle for production traits is performed in Canada using a multi-trait, random regression test-day (**TD**) model known as the Canadian Test-Day Model (Schaeffer et al., 2000). This model does not currently account for the environmental influence of pregnancy. If pregnancy significantly affects genetic evaluations of production traits, then the removal of these effects should improve the accuracy of genetic evaluations of Canadian dairy cattle.

Pregnancy effects refer to how the process of gestation influences milk production traits. Hormones released as a result of pregnancy cause an increased regression of the mammary gland (Bachman et al., 1988; Coulon et al., 1995; Brotherstone, et al., 2004; Akers, 2006). These hormones are released from the fetal placental unit at around 100 days into gestation (Bachman et al., 1988). As the fetus grows larger its nutrient demands increase (Brotherstone et al., 2004), which leaves less nutrients and energy to be partitioned toward the production of milk. The effect of pregnancy is small at the beginning of gestation and becomes larger at later stages of gestation when growth and nutrient requirements of the conceptus increase. These effects are environmental, and should not be included in the genetic representation of the cow's ability to produce milk.

The decline in milk yield as a result of pregnancy begins after 4 or 5 months of pregnancy (Bachman et al., 1988; Olori et al., 1997; Roche, 2003). On average, all Canadian dairy cattle breeds conceive at approximately 4 months of lactation (Canadian Dairy Network, 2004). For Canadian Holstein multiparous cows, Jamrozik et al. (2005) found that the average interval from calving to first service was 87.1 days, and the average interval from first service to conception was 32.5 days. Because milk production begins to decline at 4 or 5 months into gestation, and because Canadian dairy cattle conceive at approximately 4 months into lactation, many cows will begin to experience pregnancy effects that significantly influence production traits before 305 days in milk (**DIM**). Thus, TD records may be negatively influenced by pregnancy for many cows.

Another important consideration is the possible interaction between stage of lactation and stage of gestation. Olori et al. (1997) found that the effect of pregnancy was higher in mid lactation than in late lactation ($P < 0.05$). Conversely, Auran (1974) found that the depression of milk yield from the 5th to the 6th month of gestation was greater in the 10th month of production compared to earlier stages of lactation, and concluded that there was a significant ($P < 0.01$) interaction between stage of lactation and stage of gestation. Sharma et al. (1990), however, did not find a significant interaction between stage of lactation and stage of pregnancy for any of the milk production traits studied, including milk, fat and protein yield ($P > 0.05$).

Assuming pregnancy has a significant effect on dairy cattle production before 305 DIM, accounting for this effect would remove an environmental influence on production from the calculation of an animal's genetic merit. Accuracy of estimated breeding values should therefore increase after accounting for pregnancy. Another advantage of including pregnancy effects in future genetic evaluations will be to include TD records beyond 305 DIM because pregnancy will affect most TD records taken after 305 DIM. However, adding a new effect to the model increases the complexity of the model, which increases the computing time required to complete genetic evaluations. Conception dates will need to be determined, and so accurate insemination records will be needed. New variance components would need to be estimated if pregnancy effects are to be added to the model.

If pregnancy has a significant environmental impact on the TD yields of Canadian dairy cattle, then it should be included in the Canadian Test-Day Model. The objective of this study, therefore, was the phenotypic quantification of the impact of pregnancy on milk production traits for four different dairy cattle breeds using four different methods.

MATERIALS AND METHODS

Data

Data were TD records of Canadian Ayrshire (**AY**), Jersey (**JE**), Brown Swiss (**BS**) and Guernsey (**GU**) breeds. Holstein records were analyzed in a separate study. Test-day data consisted of 3,455,330 records on 195,386 cows calved from 1987 to 2007. Table 1 contains the distribution of TD records among breeds and parities for milk yield (number of TD records were similar across traits). Only first, second and third parity TD records with DIM ≥ 5 and ≤ 365 were used.

Data included days pregnant and days open (**DO**) information for each TD record. Lactation records of second, third and fourth parities were used to validate the presence of subsequent calvings. Insemination records were used to determine conception dates so that days pregnant and DO information could be calculated and included in the TD record data. Gestation length was assumed to be 280 days for AY and JE and 285 days for BS and GU (Bohmanova et al., 2006). Conception dates were assigned as the last date of insemination within 280 ± 15 or 285 ± 15 days prior to calving. Otherwise, date of conception for cows without insemination records were assigned a conception date of calving date minus 280 or 285 days. For animals with incomplete lactations (i.e., lactation still in progress when the dataset ended in 2007), the animal was assumed to have conceived at the last available insemination record. If an insemination record was unavailable for an animal, then there were two assumptions made: the animal did not conceive if the previous calving occurred before 2006 (i.e., the animal had a year or more to conceive and calve, but did not), or the animal was pregnant because the previous calving occurred after 2006 and so the subsequent calving would have occurred after the end of the dataset. If the cow was assumed pregnant, conception was assumed to occur at 130 DIM.

Each TD record was assigned an age-parity-season class. Records were assigned to one of 7 age classes for parity 1, 6 classes for parity 2 and 5 classes for parity 3. April through September was defined as season 1, and October through March was defined as season 2.

Days open

Because pregnancy effects should begin at different stages of lactation depending on when a cow conceives, DO was used in a model to investigate the impact of pregnancy on production traits. Test-day records were grouped into DO classes. Animals that did not have a subsequent calving and lactation were assumed to never have been pregnant during the lactation. While these animals could have become pregnant, but had an abortion or were culled, the assumption was that these animals were not pregnant long enough for pregnancy to have had any influence on production. Never pregnant cows were grouped together in the DO analysis. Class 1 included TD records for cows that were > 1 and $\leq$ 60 DO. Class 9 included TD records for cows that were > 270 DO and $\leq$ 305 DO, and class 10 included TD records for cows over 305 DO. Remaining DO classes (2-8) consisted of 30 day intervals. The purpose of this model was to study the impact of DO on milk production. The distribution of TD records within each DO class is given in Table 2 for four breeds. Solutions for DO effects were used to plot DO curves for milk, fat and protein yield by DIM.

Stage of pregnancy

Two models for stage of pregnancy were a) polynomial regression on days pregnant; and b) classes of days pregnant. A total of 8 pregnancy classes of 30 day intervals were created, with the 8^{th} class including all cows over 210 days pregnant. TD records of cows that were never pregnant were allocated to the 9^{th} class. Figures 1 and 2 illustrate the distribution of milk yield TD records throughout gestation for the AY breed for days pregnant and classes of days pregnant, respectively.

Interaction between stage of lactation and stage of gestation

DO classes and classes of days pregnant were used. For example, two cows within the same stage of pregnancy may be at different stages of lactation, and therefore have different DO. The TD records taken at any particular stage of pregnancy for these two animals would therefore always have different DO classes assigned to them. The purpose of this model was to study the lactation curve as pregnancy progressed within DO classes. This was to determine if the decline in milk production due to pregnancy differed depending on the stage of lactation of the cow. Solutions for interaction effects were used to plot DO curves for milk, fat and protein yield by DIM.

Models

Four fixed effects only models were used to study the impact of pregnancy on dairy cattle production traits (milk, fat and protein yield).

Model 1 used a Legendre polynomial regression on DIM within DO classes to account for pregnancy by separating cows that would begin to experience the effects of pregnancy at different stages of lactation.

The equation for Model 1 was:

$$y_{ijkl} = htd_i + \sum_{j=0}^{4} \phi_j(t) \cdot aps_{jk} + \sum_{j=0}^{4} \phi_j(t) \cdot do_{jl} + e_{ijkl} \ ,$$

where y_{ijkl} is the test-day production trait record (either milk, fat or protein yield); htd_i is the i^{th} herd test-day parity effect; aps_{jk} is the j^{th} regression coefficient for the k^{th} age parity season class; do_{jl} is the j^{th} regression coefficient of the l^{th} DO class; ϕ_j is the j^{th} Legendre polynomial for days in milk (t); and e_{ijkl} is the residual.

Model 2 included classes of days pregnant fitted within DO classes. This allowed production to be plotted over the course of gestation for each DO class.

The equation for Model 2 was:

$$y_{ijkl} = htd_i + \sum_{j=0}^{4} \phi_j(t) \cdot aps_{jk} + do:dp_{lm} + e_{ijklm} \ ,$$

where $do{:}dp_{lm}$ are classes of days pregnant fitted within days open classes.

Model 3 included a regression of Legendre polynomials on days pregnant. Let dp represent days pregnant, then

The equation for Model 3 was:

$$y_{ijk} = htd_i + \sum_{j=0}^{4} \phi_j(t) \cdot aps_{jk} + \sum_{j=0}^{4} \phi_j(dp) + e_{ijk} \ ,$$

Model 4 used days pregnant divided into classes rather than as a covariate.

The equation for Model 4 was:

$$y_{ijkl} = htd_i + \sum_{j=0}^{4} \phi_j(t) \cdot aps_{jk} + preg_l + e_{ijkl} \ ,$$

SAS Proc GLM (SAS, 2007) was used only to analyze the significance (at $P < 0.05$) of the four models. BLUPF90 (Misztal, 1999) was used to estimate the effects of the models. Solutions for effects of DO, DO by stage of pregnancy, days pregnant and stage of pregnancy were plotted to study the impact of pregnancy on production traits (milk, fat and protein yield) as well as the feasibility of the eventual use of these models in the Canadian Test-Day Model.

Because the four breeds under investigation will not produce the same levels of milk, fat and protein, the percent decline in milk, fat and protein yield as pregnancy progressed for all four breeds was also investigated. Mean yields were calculated for each stage of pregnancy in each parity. Correction factors from Model 4 were used as yield loss for a given stage of pregnancy. Percentage loss at a particular stage of gestation was calculated by dividing yield loss by the mean yield for that stage of pregnancy. Percent loss was averaged across three parities.

RESULTS AND DISCUSSION

Results for all analyses were similar across breeds and, in most cases, only results for the Ayrshire breed are shown. Furthermore, patterns of yield decline were similar across parities, with steeper declines for parities 2 and 3. As a consequence only parity 1 results for some analyses are shown.

Model 1 - Days open

Figures 3 to 6 show DO curves of parity 1 milk yield by DIM for AY, JE, BS and GU cows, respectively. Because most cows are given a dry period of 60 days before calving, the number of TD records decreased drastically for DO classes 1, 2 and 3 at around 280, 310 and 340 DIM, respectively. Consequently, predictions of yield were not plotted during the dry period, because solutions would not be based on a sufficient amount of data. Results were similar across traits and parities, although peak yields were not nearly as pronounced for fat and protein as they were for milk (results not shown). Results were similar across all breeds, with slight fluctuations for GU.

Brotherstone et al. (2004) found that accounting for DO significantly improved the goodness of fit of the model to the data for all three lactations. Schaeffer and Henderson (1972) divided cows into DO groups of 10 days per group and found significant differences between DO groups for 305-day milk yield.

Overall, cows in the ‘never pregnant’ class had the lowest milk production throughout lactation. A possible explanation for this could be that these cows had poor production and producers planned on culling these cows after their lactation, and so did not try to inseminate them. Similarly, Brotherstone et al. (2004) found that the milk production of cows that were never pregnant throughout lactation was lower, and attributed this to possible health problems such as mastitis. This proportionally lower production suggests the presence of a possible confounding effect between production level and DO. Danell (1982) found that the effects of DO were significant early in lactation when no decrease in milk yield caused by gestation should occur. This author also suggested a possible confounding effect between DO and milk production level. Conversely, Oltenacu et al. (1979) concluded that 305 day cumulative milk yield associated with differing DO periods did not vary between high and low producing cows within lactation.

Milk yield of cows with shorter DO (classes 1 to 5) showed a steep decline toward the end of lactation. Brotherstone et al. (2004) found that milk production loss increased compared to other groups toward the end of lactation only for DO classes 1, 2 and 3 (DO classes consisted of 30 day intervals).

A steep decline in yield did not occur for any of the classes of cows that became pregnant later in lactation (for DO classes 6 to 10), or for the never pregnant DO class cows. The reason is that pregnancy did not have an effect on the never pregnant DO class cows, and would only have an effect on DO classes 6 to 10 after 365 DIM (assuming the producer extends the lactations of these animals beyond 365 days). The TD records of cows that conceived later on in lactation (6 to 10 classes of DO) were not affected by pregnancy before 365 DIM because these cows had not been pregnant long enough.

The DO curves of cows with longer DO showed proportionally higher yields throughout lactation, suggesting a possible confounding effect between production level and DO. For instance, cows with higher production levels might have poor fertility (because milk production is genetically negatively correlated with fertility (Abdallah and McDaniel, 2000)). Another possibility is that producers may intentionally prolong the number of DO in order to extend the lactation of high producing cows. Schaeffer and Henderson (1972) noted that cows with shorter DO tended to produce less milk (i.e., had a lower 305-day milk yield). They indicated, however, that it was difficult discern whether cows had fewer DO because they were poor producers, or if they produced less milk because they had fewer DO. Lee et al. (1997) found a significant relationship between DO and 305-day milk yield with higher yielding cows having greater DO, which was estimated to cause an overcorrection bias of up to 70%.

Model 2 – Days open by stage of pregnancy

Solutions for classes of days pregnant fitted within DO classes were used to estimate DO curves of milk yield (Figure 7). Patterns of DO curves were similar for fat and protein yield (results not shown). Each curve was plotted from the beginning of pregnancy (beginning at different stages of lactation, depending on the number of DO). The steepness of decline was only slightly larger for parity 2 and 3 compared to parity 1. Dividing TD records into DO by classes of days pregnant resulted in so few TD records in each category that differences between parities were not accurately depicted. Patterns of milk, fat and protein yield decline were similar across all breeds, with slight fluctuations for smaller breeds (BS and GU).

Similar to Model 1, DO classes seemed to be confounded with production level, with cows that became pregnant later experiencing a higher level of production throughout the gestation period. Each milk yield curve in Figure 7 starts at 0 days pregnant, and for DO classes 2, 3 and 4, the curves began with a decline for the first 30 to 60 days in gestation. Following this, milk yield began to increase for about 60 to 90 days before declining again. In the first month or two of gestation, a large amount of energy is required for the initial growth of the embryo and its attachment to the endometrium of the uterus. This partitions energy away from milk, fat and protein production. The effect would likely be more noticeable for animals at the peak of production (cows with fewer DO). By the 18th day of gestation, the conceptus has grown large enough to occupy both uterine horns in the dairy cow, and attachment of the fetus to the uterus is complete after approximately a month of gestation (Senger, 2003, pg 289, 306). Using an equation derived by Jakobsen et al. (1957), Moe and Tyrrell (1972) calculated the efficiency for utilization of metabolizable energy for fetal tissue deposition to be only 10.5% for a 600 kg dairy cow. Most dairy cattle producers (in Ontario) do not increase the energy intake of cattle based on pregnancy (John Cant, personal communication). Cows that conceive soon after lactation begins are in a negative energy balance for a short while due to high milk production, along with rapid growth and attachment of the conceptus.

For every DO class, the decline in milk yield production began at relatively the same period of lactation (between 200 and 240 DIM). This indicates that the decline in production described by this model is not due to pregnancy, but may in fact be the natural decline in production seen as a result of mammary gland regression independent of pregnancy.

Danell (1982) found an interaction between stage of lactation and stage of gestation. DO classes were included in the model for the analysis of test-day yields with ten test-day periods as separate traits. Danell (1982) concluded that after 130 to 140 days of gestation, pregnancy began to negatively influence milk yield, and that for any given period of gestation, pregnancy effects differed depending on the test-day within the lactation. However, Danell (1982) admits the possibility of confounding effects between production level of cows and DO with higher yielding cows possibly being selected to be bred later.

Auran (1974) analyzed a model for monthly milk yield that included month of pregnancy, month of production and the interaction between them. The interaction was found to be significant ($P < 0.01$). It is possible that production level of the cows influenced DO.

Model 3 – Days pregnant

The AY breed's results for loss in milk yield as gestation progressed are presented in Figure 8 (results not shown for fat and protein yield loss). Declines in parity 2 and 3 were steeper compared to parity 1. GU, the smallest breed in the analysis, showed slight fluctuations in results. The decrease in milk yield began at around 120 days pregnant. Results were similar for fat yield loss. The decline in protein yield began sooner, at around 60 days pregnant. Milk yield begins to decline after 4 or 5 months of pregnancy (between 120 and 150 days pregnant) (Bachman et al., 1988; Olori et al., 1997; Roche, 2003). Roche (2003) studied twins for the effects of pregnancy, comparing pregnant cows to their non-pregnant twins. The decline in milk yield was found to be significant at around 5 months of pregnancy (33 weeks into lactation).

Roche (2003) found that the decline in fat and protein yields were not significant until 168 days of pregnancy (approximately 36 weeks into lactation).

There was a decline in milk yield from 0 days pregnant to 30 days pregnant (Figure 8). The average cow in the data set had fewer days open (Table 2) and the initial decline in milk yield may be due to a negative energy balance for cows at the beginning of lactation and gestation. The average gestation length for AY cattle was found to be approximately 281 days in this study. Because producers usually dry off cows for 60 days prior to calving, very few TD records remained after around 225 days of pregnancy (Figure 1). Solutions based on TD records taken after 225 days of pregnancy are not as accurate, and may cause fluctuations in the resulting yields.

Model 4 – Stage of pregnancy

The AY losses in milk, fat and protein yield as gestation progressed are presented in Figures 9 to 11, respectively. Declines in parity 2 and 3 were steeper compared to parity 1 across the three traits. GU, the smallest breed in the analysis, showed slight fluctuations in results. There was a slight fluctuation in yield loss at the very beginning of pregnancy; this was shown to be true for Model 2 and Model 3 as well, and was postulated to be a negative energy balance earlier in lactation resulting from high production and the initial rapid growth and attachment of the conceptus. The decrease in milk and fat yield for all four breeds began in the 4th class of days pregnant, at approximately the 4th month of pregnancy. The decline in protein yield began sooner, at approximately 2 months of pregnancy.

Model 4 estimates at the 8th class of days pregnant were higher than expected for parities 2 and 3, though not as drastically high as was seen for the 240th day pregnant yields estimated from Model 3. Because the 8th class incorporated TD records for cows > 210 days pregnant, there were more TD records available in this last class (Figure 2) compared to the TD records available for each of the final 60 days of pregnancy (Figure 1). This would explain why Model 4 had a much smaller fluctuation in yield loss at the end of pregnancy compared to Model 3.

Mammary gland regression independent of pregnancy may be a confounding effect in Models 3 and 4. There is a degree of mammary gland regression that occurs as lactation progresses, whether or not a cow becomes pregnant (Olori et al., 1997). Increased mammary gland regression occurs with pregnancy, as stated previously, due to the release of pregnancy hormones (Bachman et al., 1988; Coulon et al., 1995; Brotherstone et al., 2004; Akers, 2006). Therefore, declining milk production at the end of lactation includes a combination of the effects of pregnancy, as well as mammary gland regression.

Comparison among breeds

Average daily milk, fat and protein yield loss (%) by stage of pregnancy are presented in Table 3. AY losses were nearly twice as high as the losses of the JE breed. From 91 to 150 days pregnant, yield losses were very similar between AY, BS and GU for all three traits. From 151 days pregnant, however, AY percentage milk, fat and protein losses were much higher compared to respective BS and GU losses. Percentage loss in milk, fat and protein yield was similar throughout pregnancy between BS and GU, and losses were slightly smaller for JE compared to these two breeds. When comparing percentage loss of yield across the three traits within the AY breed, milk yield loss was much higher from 151 days pregnant compared to losses of fat and protein yield. This difference across traits was not seen for the other breeds, perhaps due to differences in production level between AY and the other breeds. Had percentage decline in yields been the same across breeds and across traits, one possibility would be to use these percentages as multiplicative correction factors that would apply to all four breeds and all three traits.

CONCLUSIONS

Model 1 showed that pregnancy does affect test-day yields, but the effect of DO may be confounded with production level. Unless the confounding production level effect can somehow be untangled from DO effect, this method of accounting for pregnancy would not be useful for application in the Canadian Test-Day Model.

Model 2 did not describe milk, fat and protein yield loss due to pregnancy. The results indicate that an interaction effect does not exist between stage of lactation and stage of gestation.

Including days pregnant in the model demonstrated that an increasing loss in milk, fat and protein yield was associated with increasing days pregnant. This model unfortunately cannot be used to account for the loss of milk, fat or protein yield after approximately 225 days of pregnancy due to an extreme lack of records. Unless the lack of TD records can somehow be overcome, this method of accounting for pregnancy would not be useful for application in the Canadian Test-Day Model.

Model 4 also demonstrates an increasing loss in milk, fat and protein yield as pregnancy progresses. Unlike the days pregnant model, however, the stage of pregnancy model does not experience the same lack of TD records toward the end of pregnancy. Model 4 provides the most realistic estimates of the effect of pregnancy on milk, fat and protein production, making it the most likely of the four methods to be useful for application in the Canadian Test-Day Model.

Percentage decline in yields due to pregnancy were not the same across all breeds for any of the traits studied. AY experienced the largest percentage loss in milk, fat and protein yield after approximately the 5th month of pregnancy. Differences in yield losses between JE, BS and GU were more subtle.

In conclusion, three models (Model 1, Model 3 and Model 4) demonstrated that pregnancy effects have a significant negative impact on milk, fat and protein yields of dairy cattle. Results from this study will be applied to future analyses utilizing the best method for accounting for pregnancy and studying its application in the genetic evaluation of dairy cattle.

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Table 1. Numbers of test-day records and cows in lactations 1, 2 and 3 by breed[1] and trait

	Number of test-day records			Number of cows		
Breed	Lactation 1	Lactation 2	Lactation 3	Lactation 1	Lactation 2	Lactation 3
AY	861,906	560,099	444,083	99,452	65,950	50,068
JE	509,454	345,820	254,968	63,721	43,696	31,378
BS	100,463	65,307	55,580	12,267	8,061	6,312
GU	73,856	45,261	31,453	8,726	5,506	3,687

[1]AY=Ayrshire, JE=Jersey, BS=Brown Swiss and GU=Guernsey

Figure 1. Number of milk yield test-day records for Ayrshire cows by days pregnant

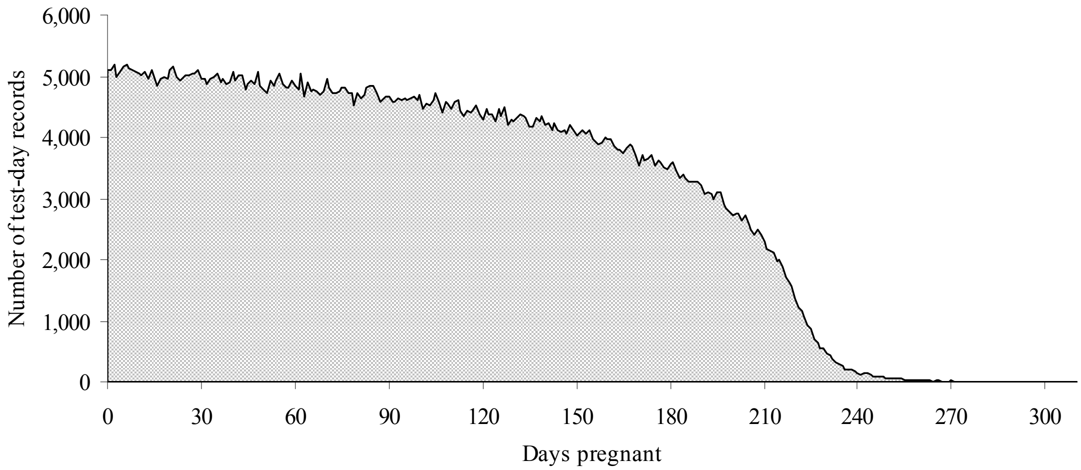

Figure 2. Number of milk yield test-day records for Ayrshire cows by classes of days pregnant

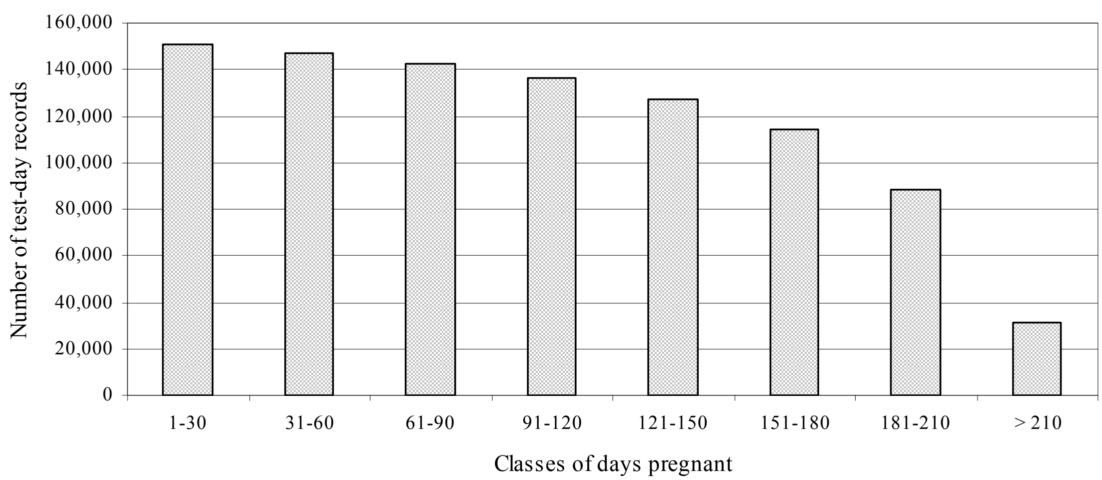

Figure 3. Ayrshire parity 1 milk yield days open (DO) curves

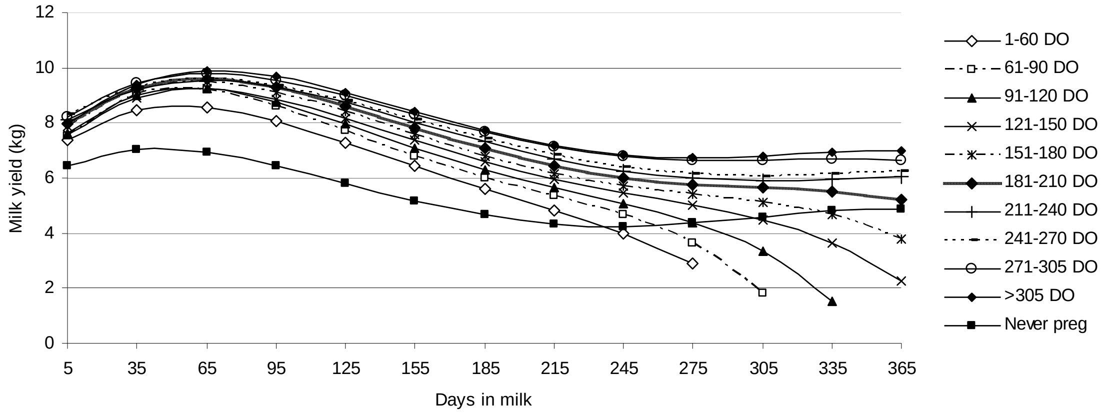

Figure 4. Jersey parity 1 milk yield days open (DO) curves

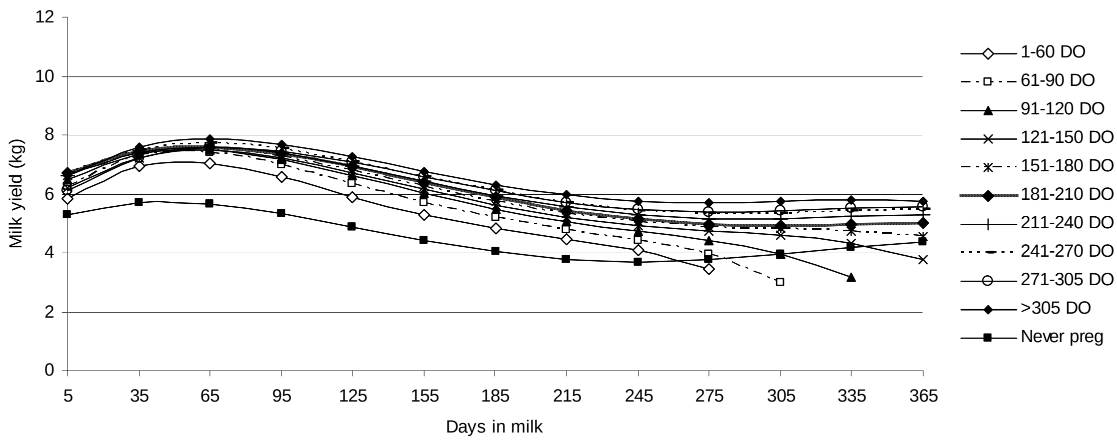

Figure 5. Brown Swiss parity 1 milk yield days open (DO) curves

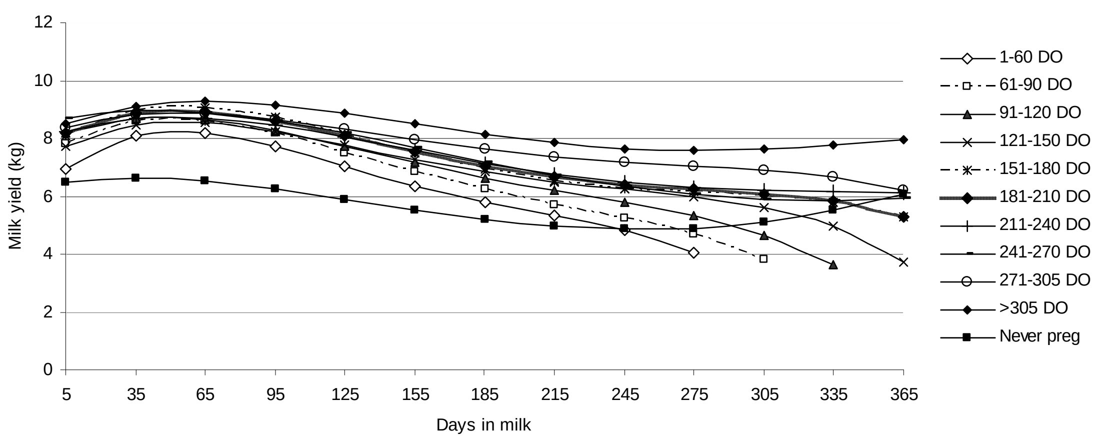

Figure 6. Guernsey parity 1 milk yield days open (DO) curves

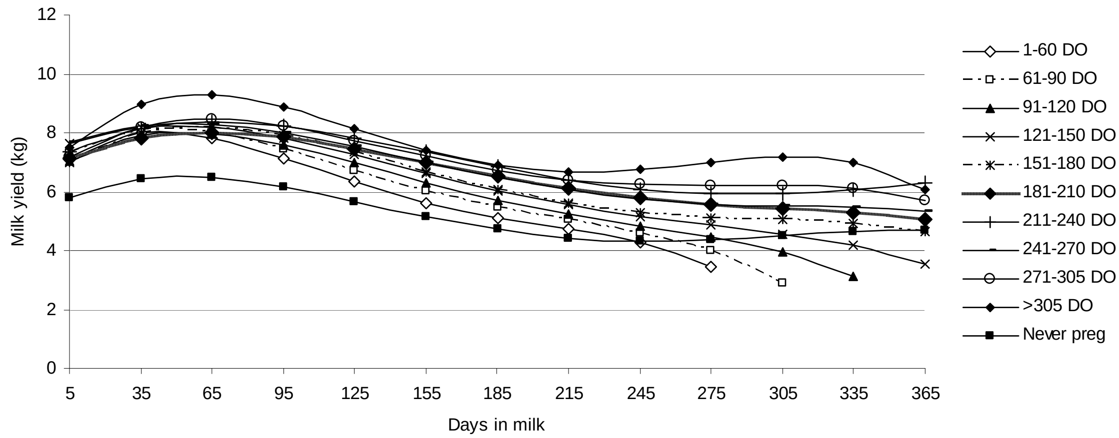

Figure 7. Ayrshire parity 1 milk yield days open (DO) curves

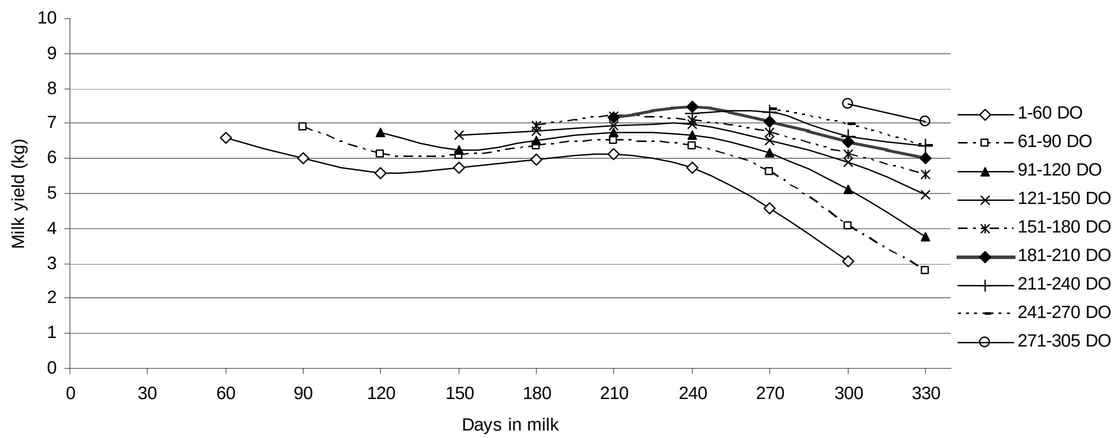

Figure 8. Milk yield loss as pregnancy progresses for the Ayrshire breed by parity (Model 3)

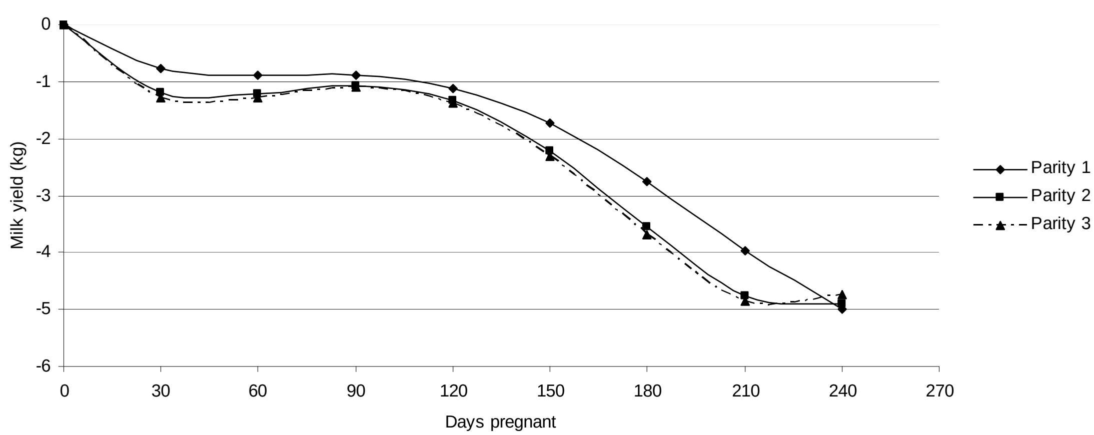

Figure 9. Milk yield loss as pregnancy progresses for the Ayrshire breed (Model 4)

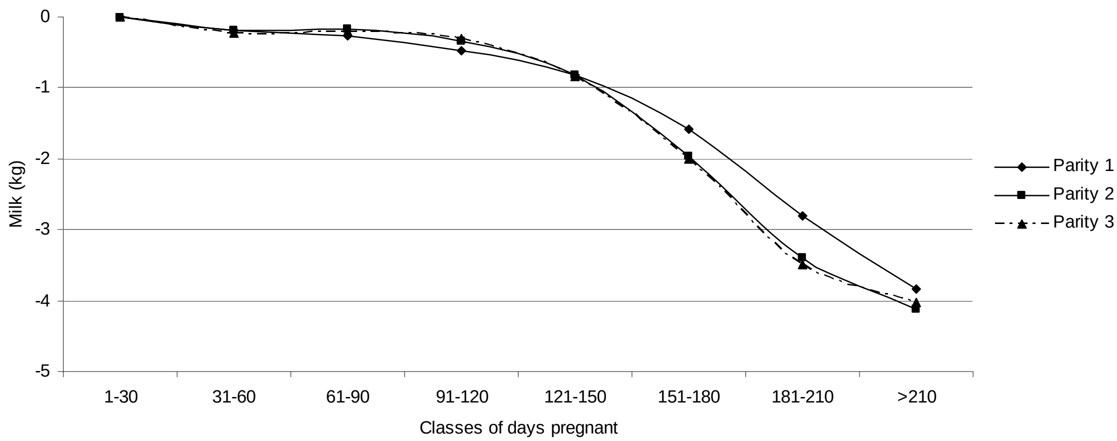

Figure 10. Fat yield loss as pregnancy progresses for the Ayrshire breed (Model 4)

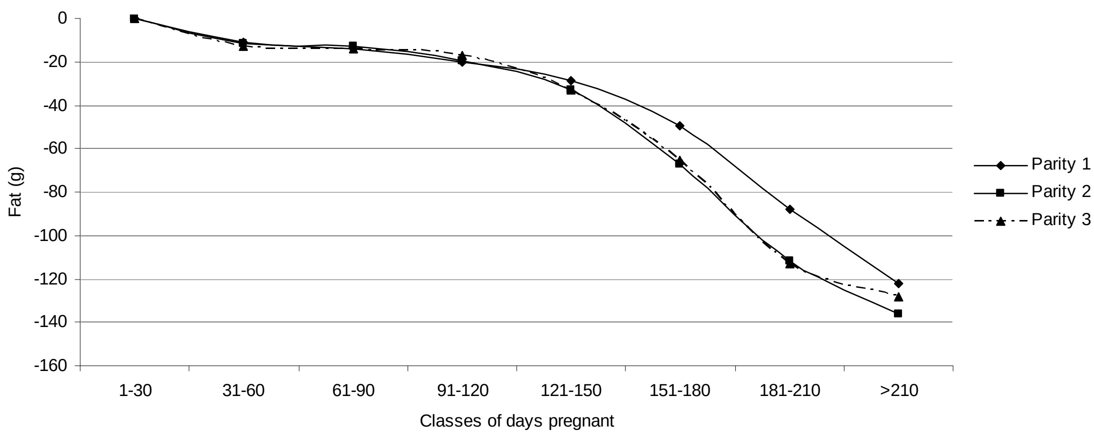

Figure 11. Protein yield loss as pregnancy progresses for the Ayrshire breed (Model 4)

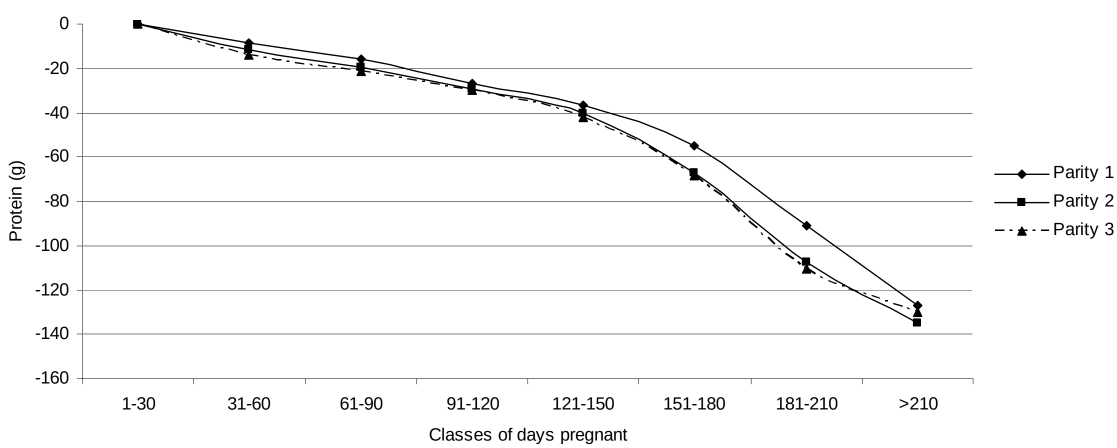

Table 2. Distribution of test-day (TD) records within each days open class by breed and parity

Days open class	Days Open	Ayrshire Proportions of TD records (%) Parity 1	Parity 2	Parity 3	Jersey Proportions of TD records (%) Parity 1	Parity 2	Parity 3	Brown Swiss Proportions of TD records (%) Parity 1	Parity 2	Parity 3	Guernsey Proportions of TD records (%) Parity 1	Parity 2	Parity 3
1	1-60 d*	3.6	4.0	4.0	4.9	5.2	4.9	5.1	5.1	4.7	3.8	3.9	3.6
2	61-90 d*	19.5	21.8	20.3	22.5	22.2	21.0	19.6	19.8	17.6	18.7	18.3	16.3
3	91-120 d*	20.2	20.5	19.1	20.7	20.8	19.6	18.3	18.7	17.1	18.4	16.8	15.7
4	121-150 d*	14.9	14.3	13.8	14.5	14.5	14.4	15.3	15.3	14.2	12.6	12.5	11.3
5	151-180 d*	9.8	8.7	8.6	8.3	8.0	8.3	9.3	8.9	9.1	8.5	7.7	8.3
6	181-210 d*	6.3	5.6	5.7	5.1	4.9	5.1	6.4	6.5	6.6	5.6	5.4	5.3
7	211-240 d*	3.9	3.5	3.9	3.4	3.2	3.5	4.2	3.8	4.3	3.8	3.6	3.9
8	241-270 d*	2.6	2.3	2.4	2.2	2.1	2.2	3.1	2.7	3.5	1.9	2.4	2.6
9	271-305	2.0	1.6	1.7	1.8	1.7	1.8	2.6	2.1	2.8	1.7	1.6	1.6
10	>305	1.6	1.4	1.6	1.8	1.7	1.9	2.7	2.7	2.8	2.0	1.8	2.1
never pregnant		15.7	16.4	18.9	14.9	15.8	17.4	13.5	14.4	17.4	23.0	26.0	29.4

*d=days

Table 3. Average daily milk, fat and protein yield loss (%) by stage of pregnancy

Classes of days pregnant	Milk Ayrshire	Milk Jersey	Milk Brown Swiss	Milk Guernsey	Fat Ayrshire	Fat Jersey	Fat Brown Swiss	Fat Guernsey	Protein Ayrshire	Protein Jersey	Protein Brown Swiss	Protein Guernsey
1-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
91-120	1.1	0.2	1.1	1.4	1.5	0.8	1.4	1.8	2.9	1.6	2.5	2.9
121-150	3.7	2.5	3.5	3.3	3.2	2.2	3.3	2.5	4.9	3.2	4.8	4.1
151-180	10.7	6.6	7.4	7.7	7.7	4.7	5.4	5.1	9.6	5.6	7.5	7.0
181-210	22.5	12.4	13.9	14.9	15.8	8.7	9.6	9.8	18.6	10.3	13.1	13.3
>210	32.2	17.3	20.6	23.2	22.1	12.3	14.7	15.0	27.3	14.9	20.0	21.7