Effect of pregnancy on milk yield of Canadian dairy cattle

J. Bohmanova[1], F. Miglior[2,3], M. Kelly[1], G. Kistemaker[3], 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 conceptus 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 impact of pregnancy on milk yield depends on lactation stage. The effect is higher in mid lactation than in late lactation (Olori et al., 1997). Haile-Mariam et al. noted that ignoring in the analysis the effect of day of gestation at test-day over-estimates milk yield at the beginning of the lactation and under-estimates it at the end of the lactation (2003).

Cows with higher milk yield during early lactation have longer days open and longer days open increases subsequent yield (Lee et al., 1997). Longer days open in the previous lactation positively affect test-day milk and component yields. Cows with longer previous days open have higher milk yield in the subsequent lactation because they had more time to renew body fat that is used in the next lactation. (Sadek and Freeman, 1992). Funk et al. (1987) reported that the effect of previous and present days open on milk yield is similar across parities. The effect of previous days open on test-day milk yield is greater in later stages of lactation than in earlier stages (Bormann et al., 2002). The length of days open is also associated with the shape of lactation curve. Cows that conceive shortly after calving had lower persistency (Brotherstone et al., 2004).

The objective of this study was to evaluate effect of pregnancy on milk production using test-day milk yield records and insemination records of Canadian dairy breeds.

MATERIAL AND METHODS

Data were Ayrshire (AY), Brown Swiss (BS), Canadienne (CN), Guernsey (GU), Holstein (HO), Jersey (JE) and Milking Shorthorn (MS) test-day, lactation and insemination records. Test-day (TD) data consisted of 48.4 million records on 2.8 million cows calved from 1985 to 2006 (Table 1). Only first, second and third parity TD records taken at ≤ 365 days in milk were used. A total amount of 3.6 million lactation records of second, third and fourth parity were used to validate presence of subsequent calving. The insemination data set consisted of 10.3 million records recorded from 1997 to 2006 (Table 2).

The conception date of the subsequent lactation was determined for cows with insemination records 285±10 days prior calving as the day of last insemination and for cows without insemination records as (calving date – 285 days). Gestation length of 285 days was assumed for all breeds. The average gestation length of cows with a confirmed conception date by insemination records is shown in Table 3.

Days open

The number of days each cow was open (days open), i.e. in which day of milk she became pregnant, was calculated as difference between her calving and conception date. The average days open ranged from 113 days (first lactation of MS) to 189 days (third lactation of BS), viz. Table 4. Cows were divided into twelve classes of days open. Animals without subsequent calving were assumed to never have become pregnant during the lactation and were assigned into a separate class 'not pregnant'. However, some of them could have been pregnant and due to abortion or culling did not have a subsequent lactation. Cows that became pregnant in less than 60 days of milk were assigned into class 'p1-2'. Class 'p3' covered cows that became pregnant in their third month of milk and, similarly, classes were defined every 30 days. The last class, 'p11' included animals that became pregnant after 310 days. The milk yield of a 305 day lactation is not affected by pregnancy in this group. As shown in Table 5, 71%, 68% and 61% of first, second and third parity Holstein cows, respectively, had subsequent calving and majority of these cows became pregnant between 3 and 5 months of milk.

Stage of pregnancy

Test-day records were divided into ten classes of stage of pregnancy, one class for each month of pregnancy. Class 9 covered observations from those cows that were never pregnant. Test-day records from cows that had a subsequent calving but taken when the cow was not yet pregnant were assigned into class 0. As given in Table 6, 46%, 43% and 36% of first, second and third parity TD records were measured when cows were open.

Models

Two models were used to account for effect of pregnancy. Model 1 considered differences between stages of lactations. In this model the impact of increased days open on shape of lactation curve was investigated. The following model was applied:

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

Where y is the test-day milk 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 j^{th} regression coefficient of l^{th} days open class, Φ is the Legendre polynomial of order 4 for days in milk t, and e is the residual.

The second model measures the impact of days pregnant on milk production:

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

Where y is the test-day milk 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, $preg_l$ is l^{th} stage of pregnancy class (months), Φ is the Legendre polynomial of order 4 for days in milk t, and e is the residual. BLUPF90IOD (Tsuruta et al., 2001), a program that handles large data sets using iteration on data technique, was used to run the analyses. Solutions for effects of days open and stage of pregnancy from both models were then plotted for all breeds.

RESULTS

Figures 1 to 3 show the lactation curves of days open classes for first parity cows in Holstein, Ayrshire and Jersey breed, respectively. The pattern was similar for the three breeds. Overall non pregnant cows had the lowest milk production. Milk production of cows with short days open classes tended to drop milk production significantly in the last part of lactation. Cows with longer days open had proportionally higher milk yield. The effect of days open on milk production was also investigated in second and third parity, and effect on milk production was similar to that of first parity. A similar pattern was observed in the other 4 breeds analyzed (see Appendix).

Figures 4 to 6 show the effect of stage of pregnancy on milk yield in the first three parities for Holstein, Ayrshire and Jersey breeds, respectively. The decline of milk production was observed in all breeds after 4 months of pregnancy. The decline was steeper in second and third parity cows. Table 7 summarizes the average daily decline of milk yield in the first three parities for each breed after 4 months of pregnancy until the end of gestation.

Analysis is in progress in order to verify if the decline in milk production could be overestimated due to the confounding effect of mammary gland regression not related to pregnancy.

CONCLUSION

Preliminary results have shown the impact of pregnancy on milk production using two different approaches (days open and stage of pregnancy). The effect of days open seems confounded with the production level of the cows. That is, more highly productive cows tend to have longer days open likely due to physiological competition between high milk production and reproductive cycle of the cow. Also, management may complicate matters further because more highly productive cows may be voluntarily bred later than average production cows.

On the other hand, stage of pregnancy provides more realistic estimate of effect of pregnancy on milk production. However, this approach does not account for interaction between gestation and lactation stage. Thus, work is in progress in order to validate the magnitude of decline in milk production by stage of pregnancy.

Table 1: Number of test-day records and number of cows in first, second and third lactation

	Number of TD records			Number of cows		
Breed	**Lactation 1**	**Lactation 2**	**Lactation 3**	**Lactation 1**	**Lactation 2**	**Lactation 3**
AY	852,941	551,043	401,257	99,395	65,412	47,626
BS	99,551	64,534	48,539	12,192	7,957	5,894
CN	20,417	12,663	8,549	2,451	1,510	1,029
GU	74,981	45,782	29,660	9,021	5,679	3,667
HO	21,492,378	14,128,906	9,500,503	2,577,168	1,724,841	1,169,147
JE	501,077	338,103	236,888	63,342	43,073	30,148
MS	12,112	7,807	5,704	1,602	1,091	791
All breeds	23,053,457	15,148,838	10,231,100	2,765,171	1,849,563	1,258,302

Table 2: Number of records and cows in insemination data set and year of first insemination record

Breed	Records	Cows
AY	326,602	62,806
BS	44,003	9,470
CN	7,562	1,427
GU	15,902	3,552
HO	9,754,092	1,923,903
JE	181,107	41,079
MS	4,380	1,263
All breeds	10,333,648	2,043,500

Table 3: Pregnancy length of first, second and third parity cows

Breed	Lactation 1	Lactation 2	Lactation 3
AY	282	281	281
BS	286	285	285
CN	282	281	281
GU	284	283	284
HO	280	280	280
JE	280	279	279
MS	281	280	280

Table 4: Current days open for first, second and third lactations

Breed	Lactation 1	Lactation 2	Lactation 3
AY	126	120	153
BS	127	126	189
CN	124	120	163
GU	130	122	150
HO	133	134	159
JE	126	123	148
MS	117	113	141

Table 5: Percentage of Holstein cows in each days open class

Class	Lactation 1	Lactation 2	Lactation 3
p1-2	7%	6%	5%
p3	19%	18%	15%
p4	16%	15%	13%
p5	11%	11%	9%
p6	7%	7%	6%
p7	4%	5%	4%
p8	3%	3%	3%
p9	2%	2%	2%
p10	1%	1%	1%
p11	2%	1%	4%
not pregnant	29%	32%	39%

Table 6: Percentage of test-day records in each stage of pregnancy class in Holsteins

Class	Lactation 1	Lactation 2	Lactation 3
0	25.8%	25.6%	25.4%
1	6.6%	6.4%	5.5%
2	6.8%	6.6%	5.6%
3	6.7%	6.5%	5.5%
4	6.6%	6.3%	5.3%
5	6.3%	6.0%	5.0%
6	5.8%	5.4%	4.5%
7	4.9%	4.2%	3.4%
8	1.8%	1.3%	1.0%
9 (not pregnant)	28.6%	31.8%	38.8%

Table 7: Average milk production from 5 to 305 days in milk and decline of daily milk yield from 4 month of pregnancy in kg/month

	Average milk production (kg)			Decline of milk production (kg/month)		
Breed	**Lactation 1**	**Lactation 2**	**Lactation 3**	**Lactation 1**	**Lactation 2**	**Lactation 3**
AY	19.5	22.0	23.1	-0.9	-1.0	-0.9
BS	20.1	23.5	25.0	-0.7	-0.9	-0.8
CN	14.2	16.6	17.8	-0.6	-0.3	-0.7
GU	17.9	19.9	20.5	-0.6	-0.9	-0.7
HO	25.3	29.2	30.8	-1.0	-1.3	-1.3
JE	16.7	19.4	20.6	-0.5	-0.6	-0.7
MS	18.4	21.2	22.7	-0.6	-0.6	-0.5

Figure 1: Lactation curves for first lactation of Holstein cows never pregnant (np), pregnant in their first month in milk (p1), pregnant in second (p2), third (p3), fourth (p4), fifth(p5), sixth (p6), seventh (p7), eight (p8), ninth (p9), tenth (p10) month in milk and pregnant after 11 month in milk (p11)

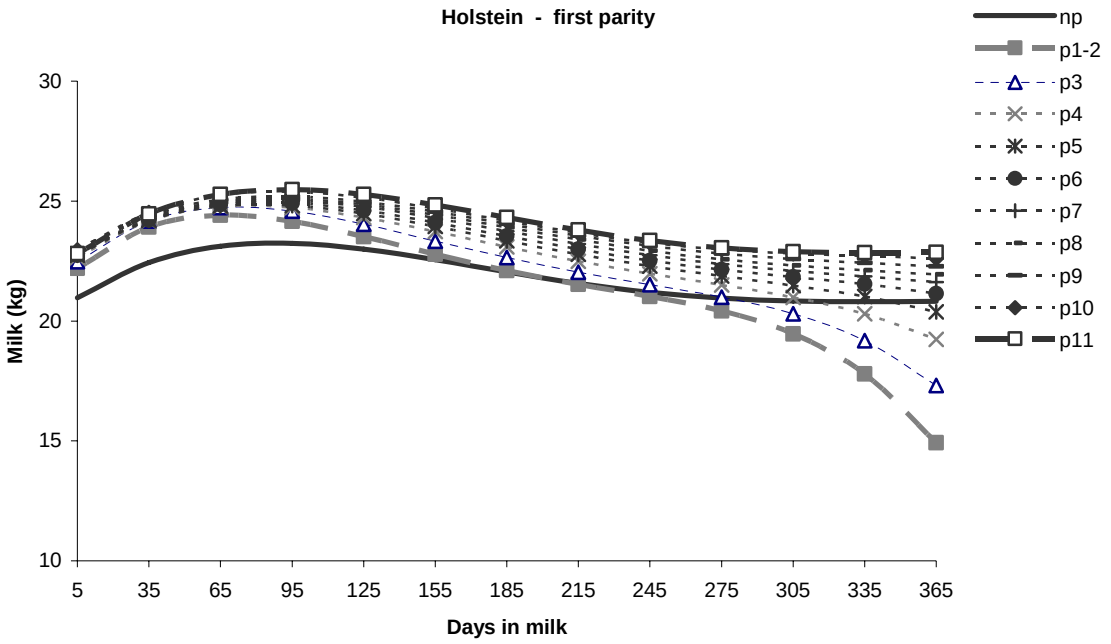


Figure 2: Lactation curves for first lactation of Ayrshire cows never pregnant (np), pregnant in their first month in milk (p1), pregnant in second (p2), third (p3), fourth (p4), fifth(p5), sixth (p6), seventh (p7), eight (p8), ninth (p9), tenth (p10) month in milk and pregnant after 11 month in milk (p11)

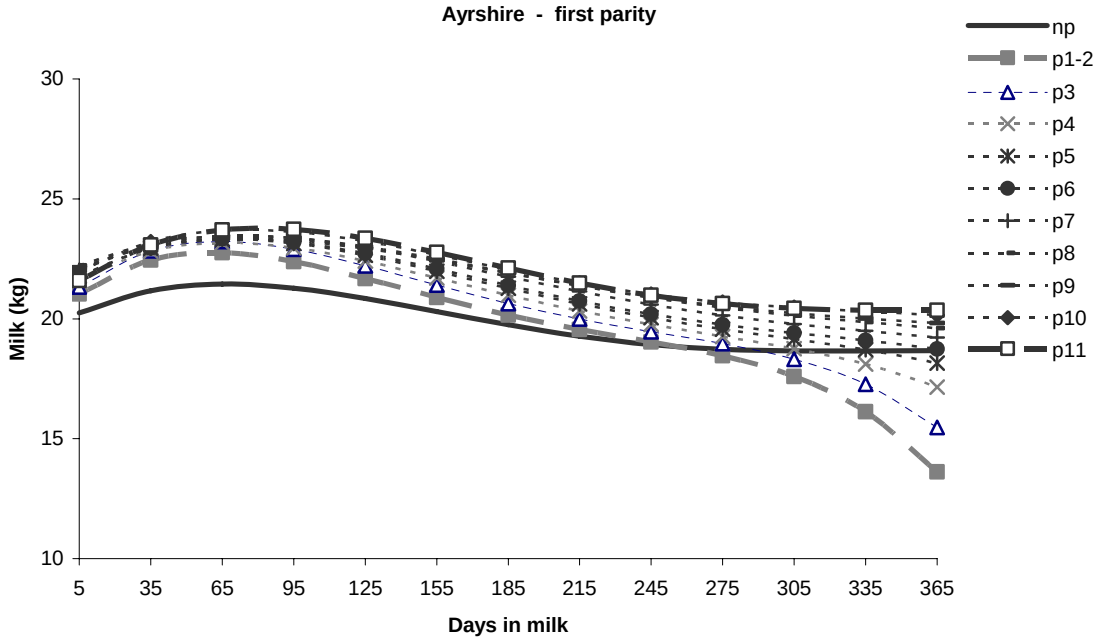


Figure 3: Lactation curves for first lactation of Jersey cows never pregnant (np), pregnant in their first month in milk (p1), pregnant in second (p2), third (p3), fourth (p4), fifth(p5), sixth (p6), seventh (p7), eight (p8), ninth (p9), tenth (p10) month in milk and pregnant after 11 month in milk (p11)

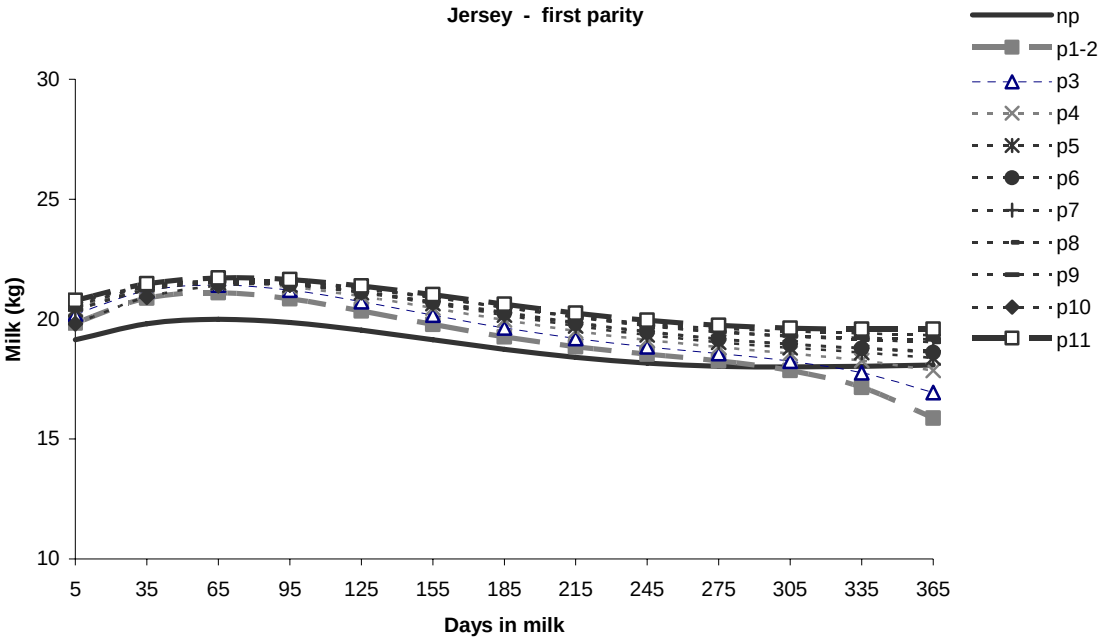


Figure 4: Estimated effect of month of gestation on milk yield of first, second and third parity of Holstein cows

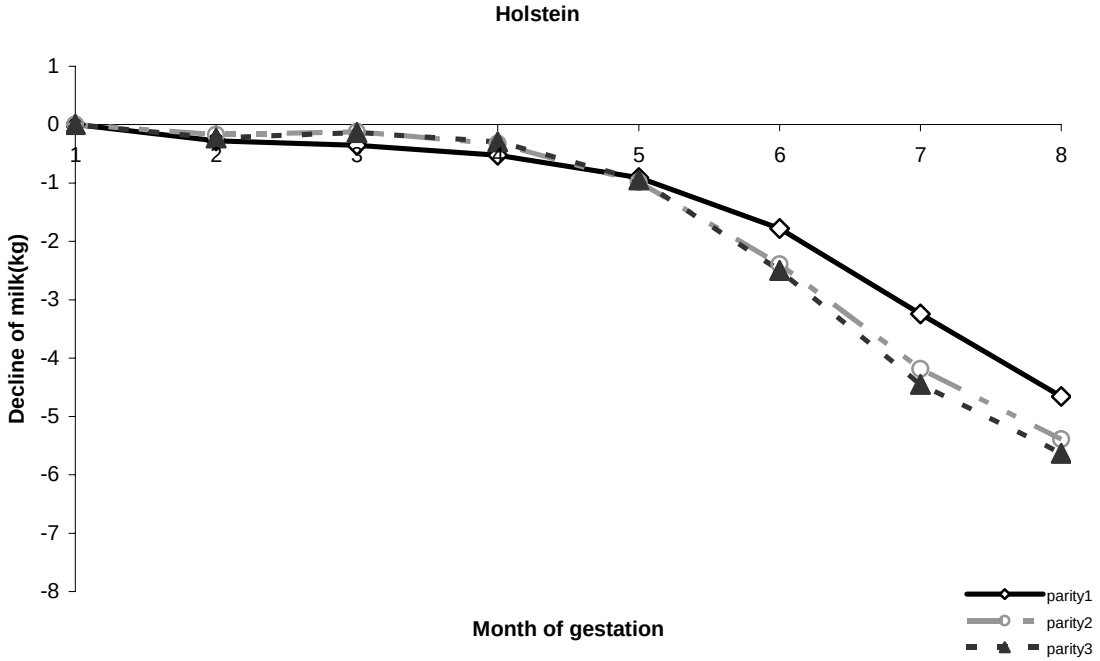


Figure 5: Estimated effect of month of gestation on milk yield of first, second and third parity of Ayrshire cows

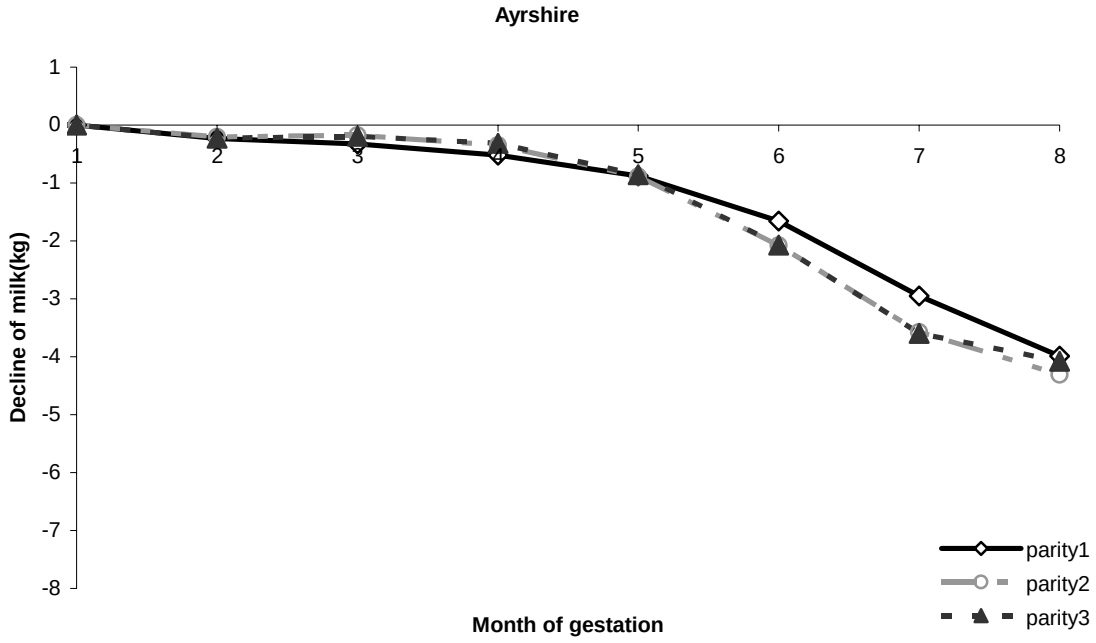


Figure 6: Estimated effect of month of gestation on milk yield of first, second and third parity of Jersey cows

APPENDIX

REFERENCES

Akers, R. M. 2006. Major advances associated with hormone and growth factor regulation of mammary growth and lactation in dairy cows. J Dairy Sci. 89(4):1222-1234.

Bell, A. W., R. Slepetis, and R. A. Ehrhardt. 1995. Growth and accretion of energy and protein in the gravid uterus during late pregnancy in Holstein cows. J Dairy Sci. 78(9):1954-1961.

Bormann, J., G. R. Wiggans, T. Druet, and N. Gengler. 2002. Estimating effects of permanent environment, lactation stage, age, and pregnancy on test-day yield. J. Dairy Sci. 85(1):263-.

Brotherstone, S., R. Thompson, and I. M. S. White. 2004. Effects of pregnancy on daily milk yield of Holstein-Friesian dairy cattle. Livest. Prod. Sci. 87(2-3):265-269.

Funk, D. A., A. E. Freeman, and P. J. Berger. 1987. Effects of previous days open, previous days dry, and present days open on lactation yield. J Dairy Sci. 70(11):2366-2373.

Haile-Mariam, M., P. J. Bowman, and M. E. Goddard. 2003. Genetic and environmental relationship among calving interval, survival, persistency of milk yield and somatic cell count in dairy cattle. Livest. Prod. Sci. 80(3):189-200.

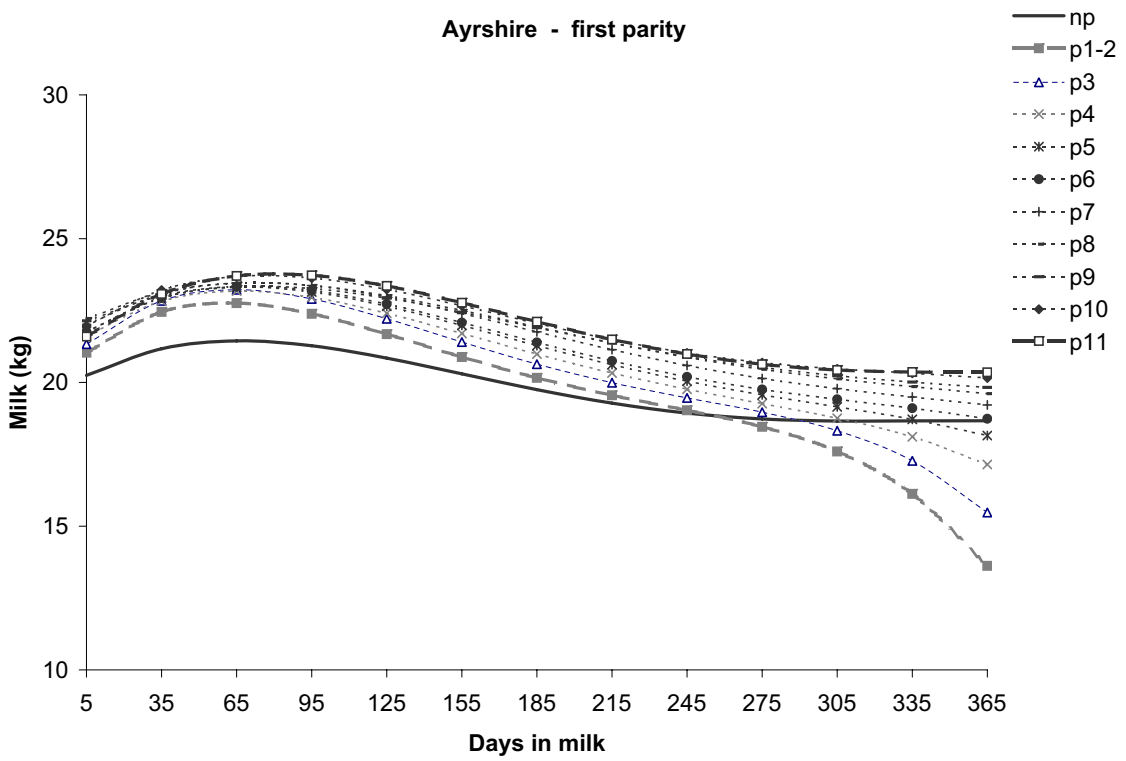
Lee, J. K., P. M. VanRaden, H. D. Norman, G. R. Wiggans, and T. R. Meinert. 1997. Relationship of yield during early lactation and days open during current lactation with 305-day yield. J Dairy Sci. 80(4):771-776.

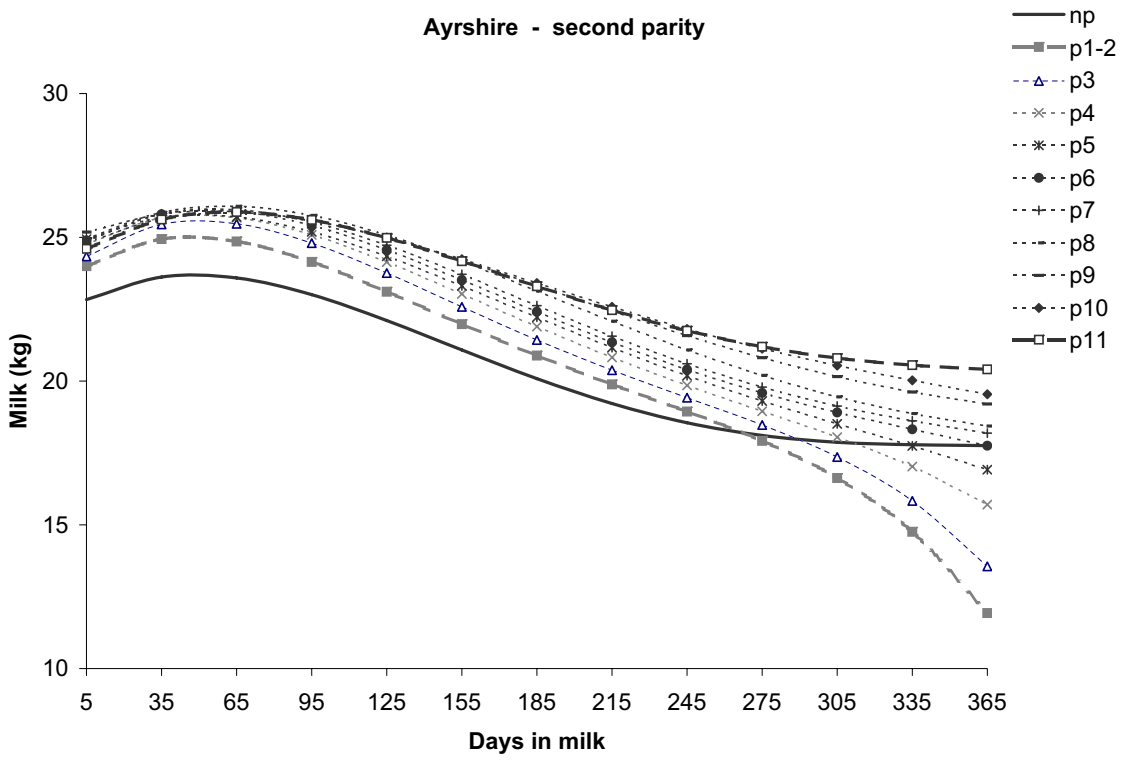
Olori, V. E., S. Brotherstone, W. G. Hill, and B. J. McGuirk. 1997. Effect of gestation stage on milk yield and composition in Holstein Friesian dairy cattle. Livest. Prod. Sci. 52(2):167-176.

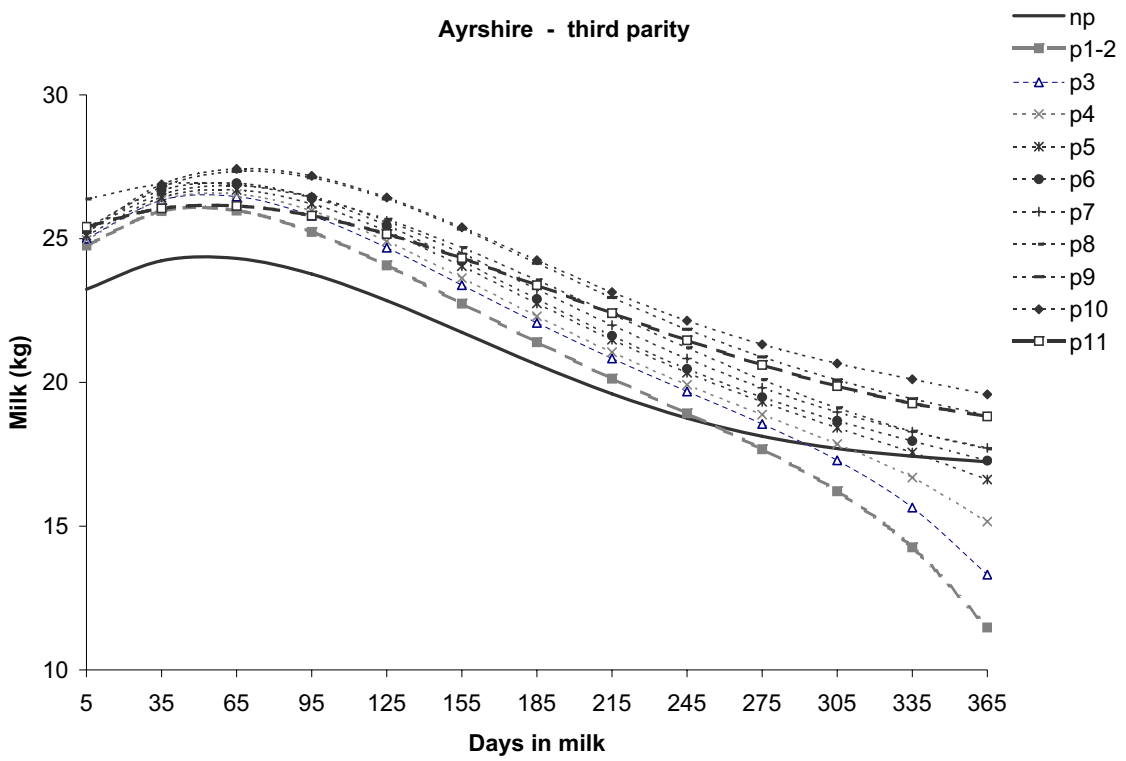
Roche, J. R. 2003. Effect of pregnancy on milk production and bodyweight from identical twin study. J Dairy Sci. 86(3):777-783.

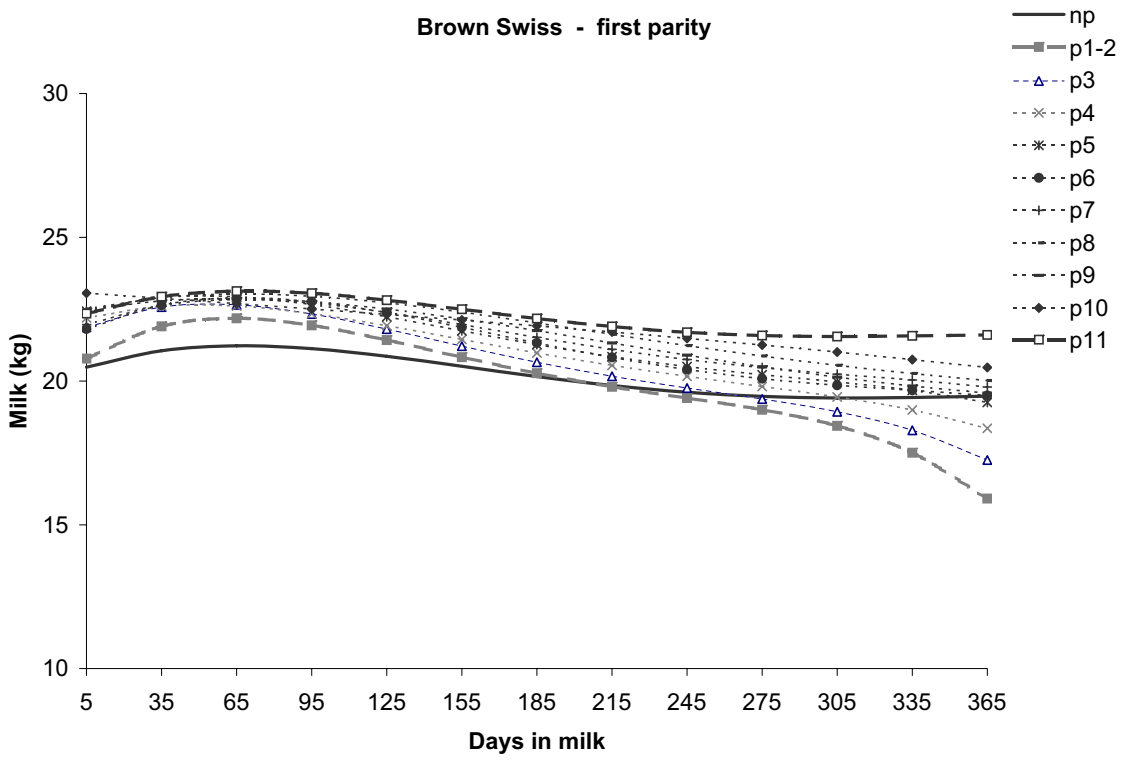
Sadek, M. H. and A. E. Freeman. 1992. Adjustment factors for previous and present days open considering all lactations. J. Dairy Sci. 75(1):279-287.

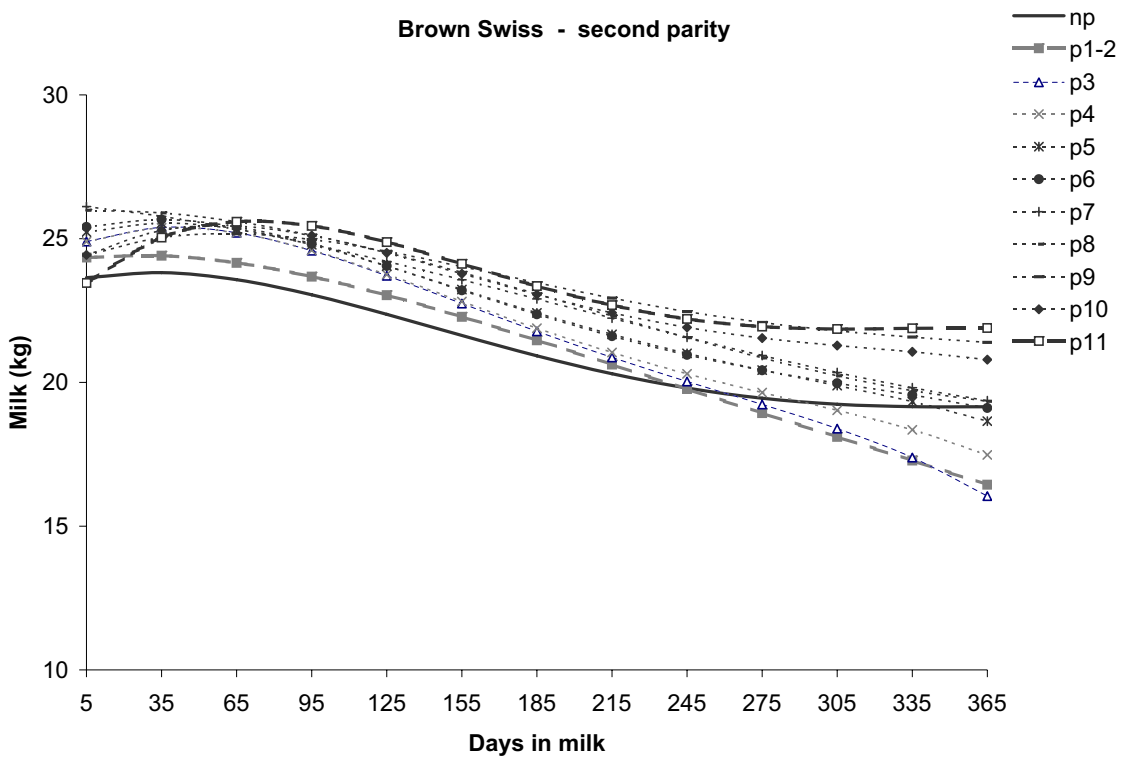
Tsuruta, S., I. Misztal, and I. Stranden. 2001. Use of the preconditioned conjugate gradient algorithm as a generic solver for mixed-model equations in animal breeding applications. J. Anim Sci. 79(5):1166-1172.

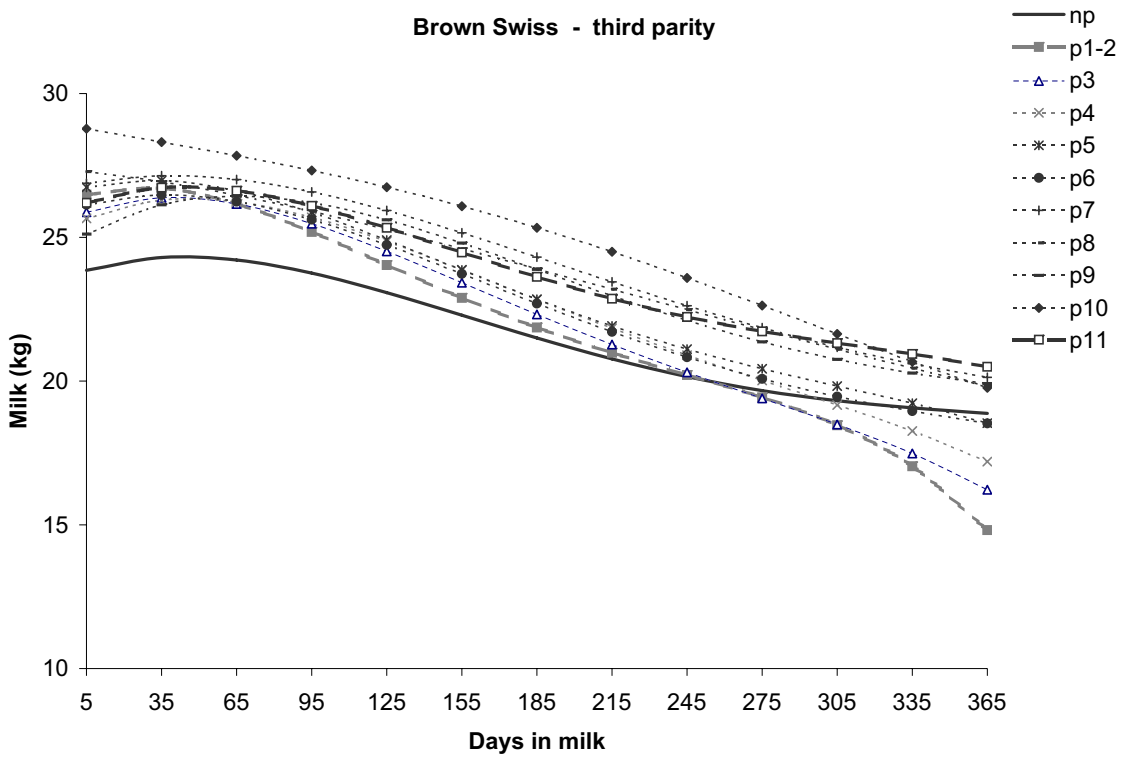

Ayrshire - first parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

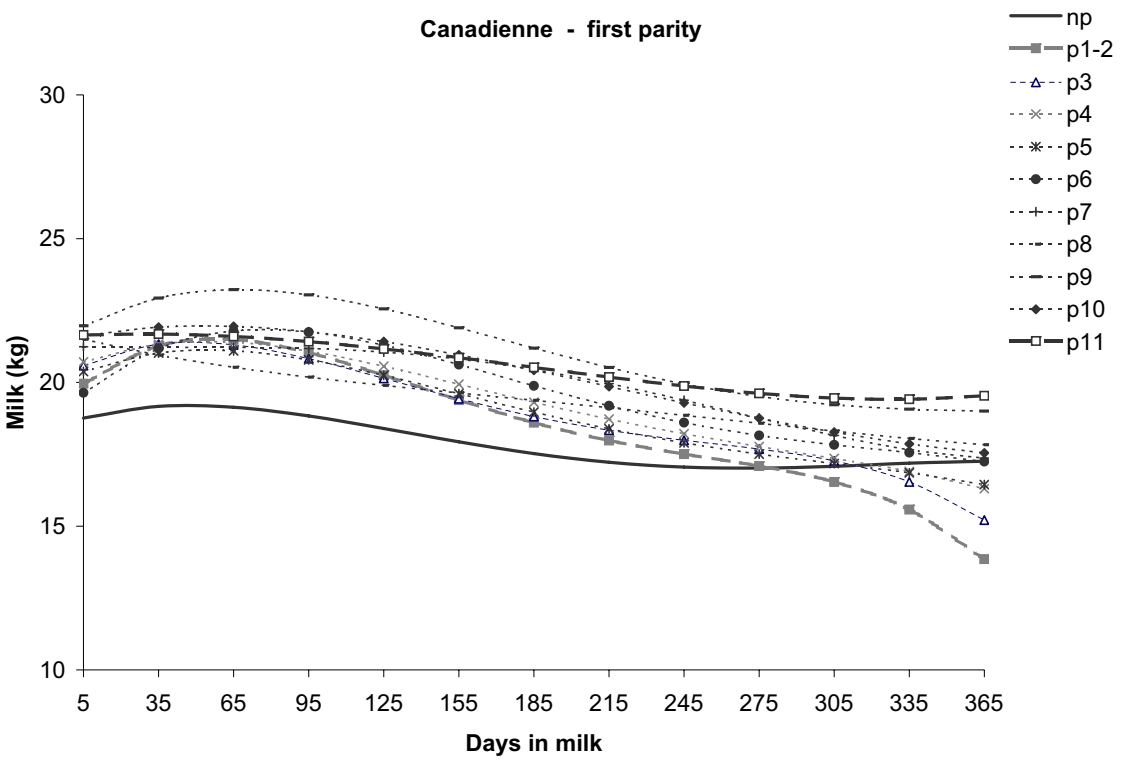

Ayrshire - second parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

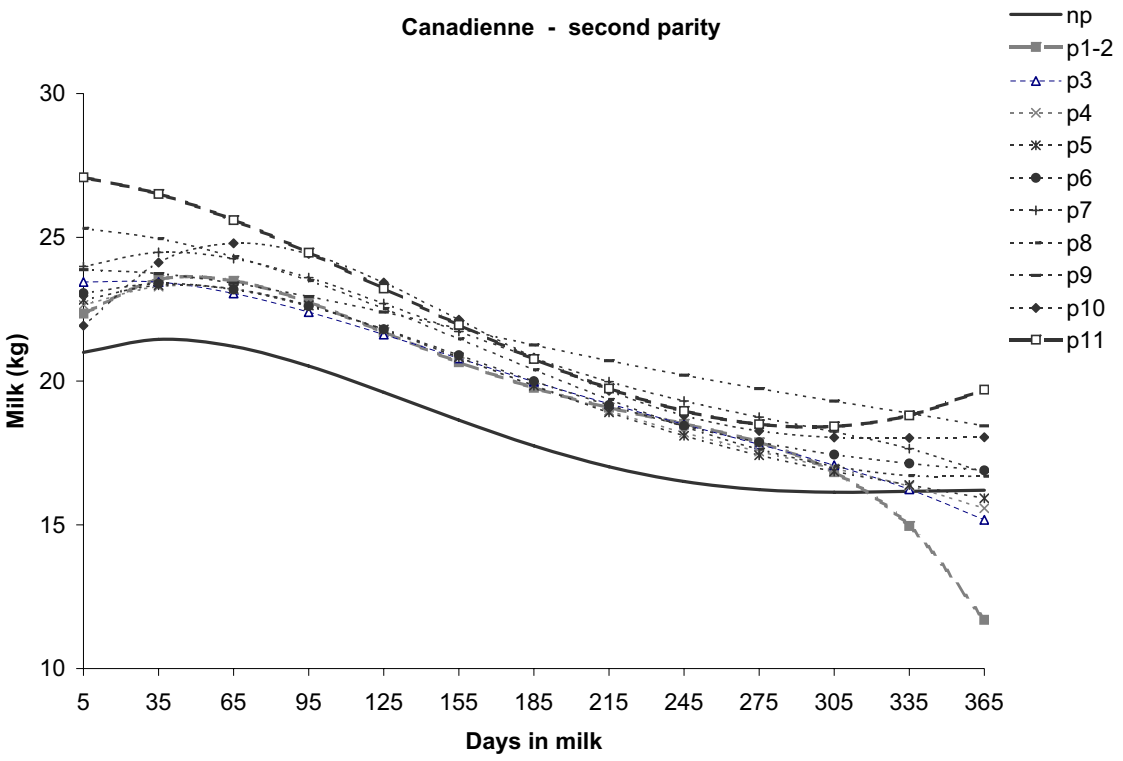

Ayrshire - third parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

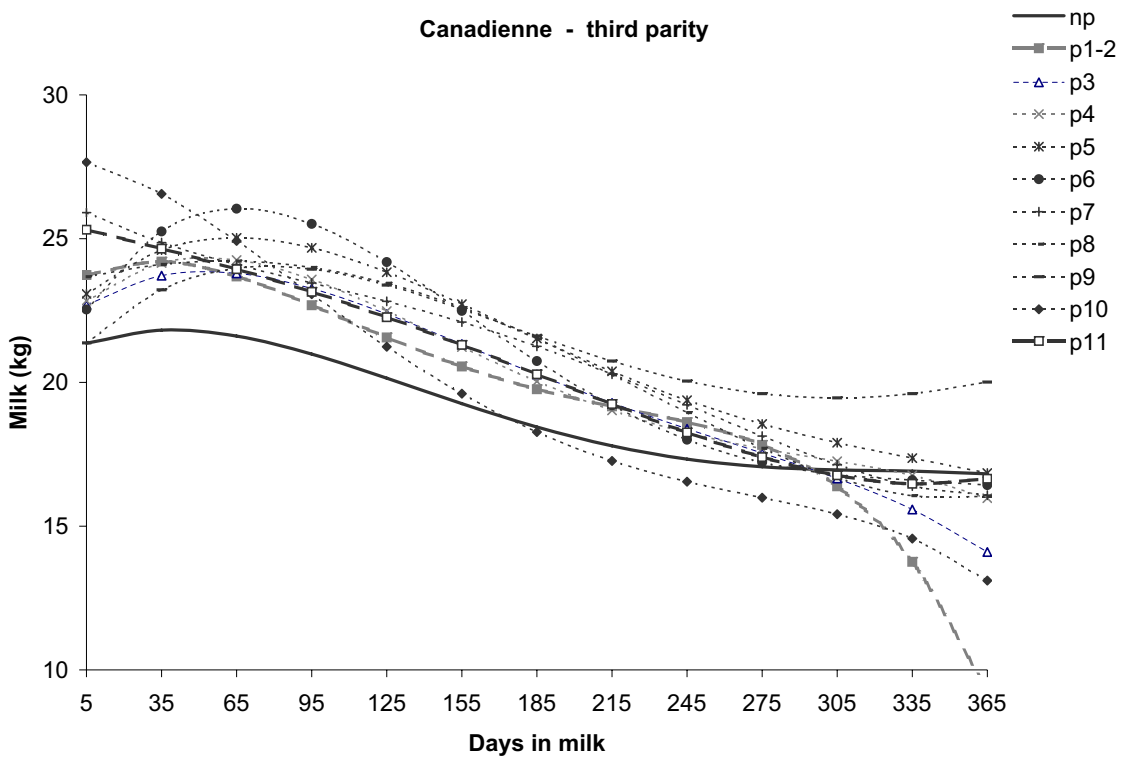

Brown Swiss - first parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

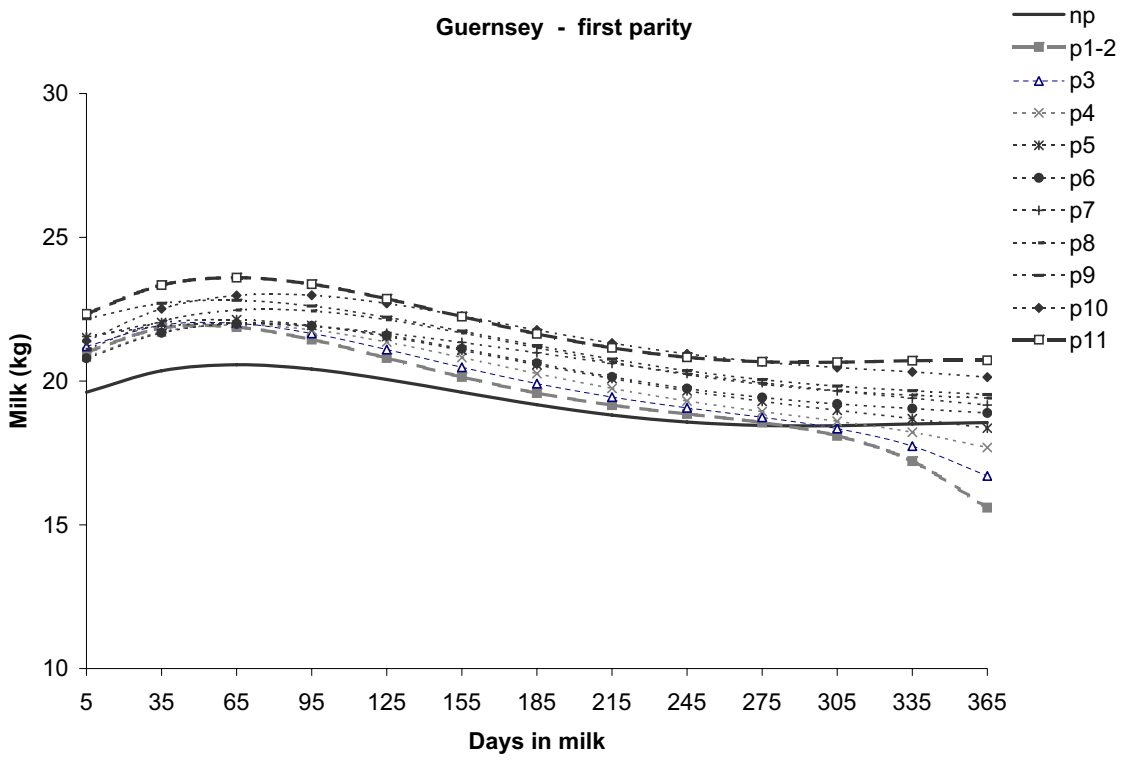

Brown Swiss - second parity
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11
Milk (kg)
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
Days in milk

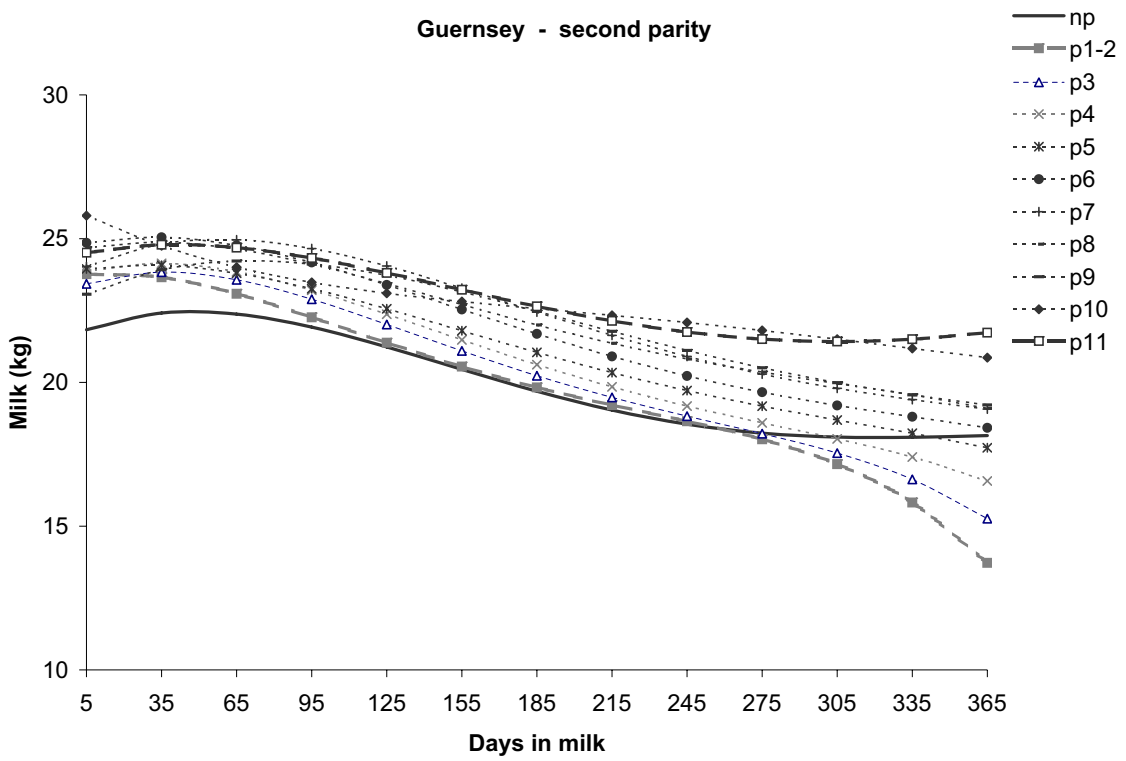

Brown Swiss - third parity
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11
Milk (kg)
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
Days in milk

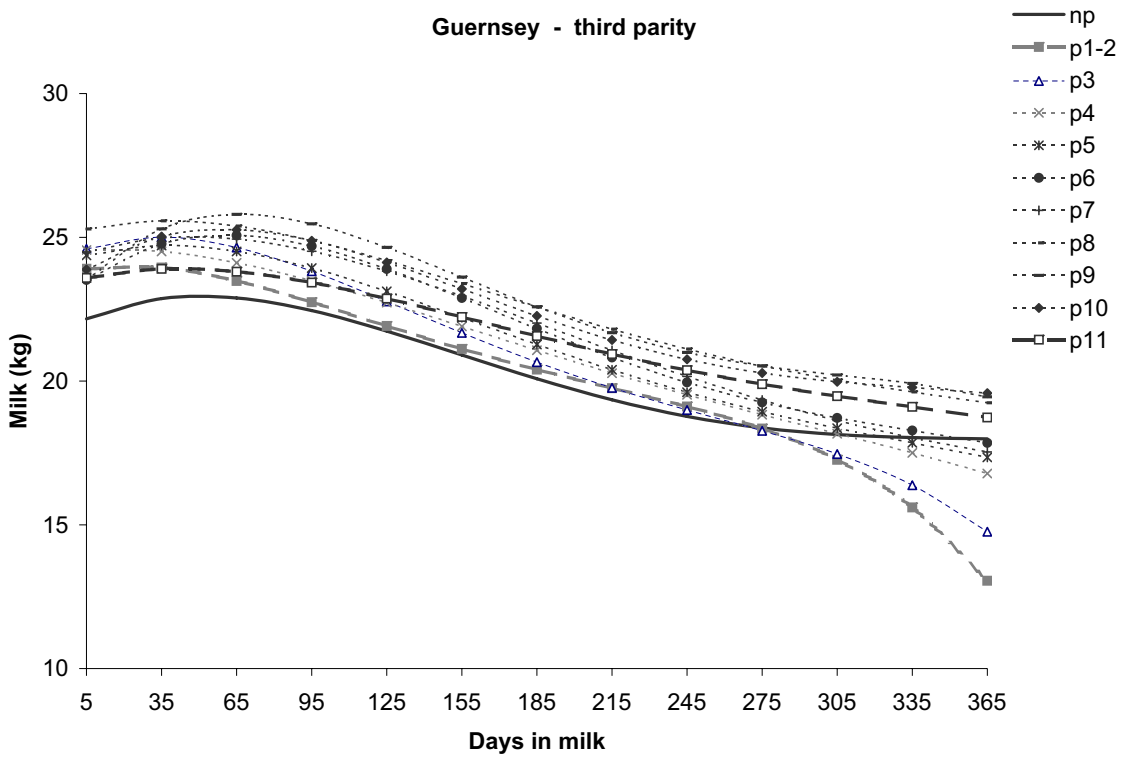

Canadienne - first parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

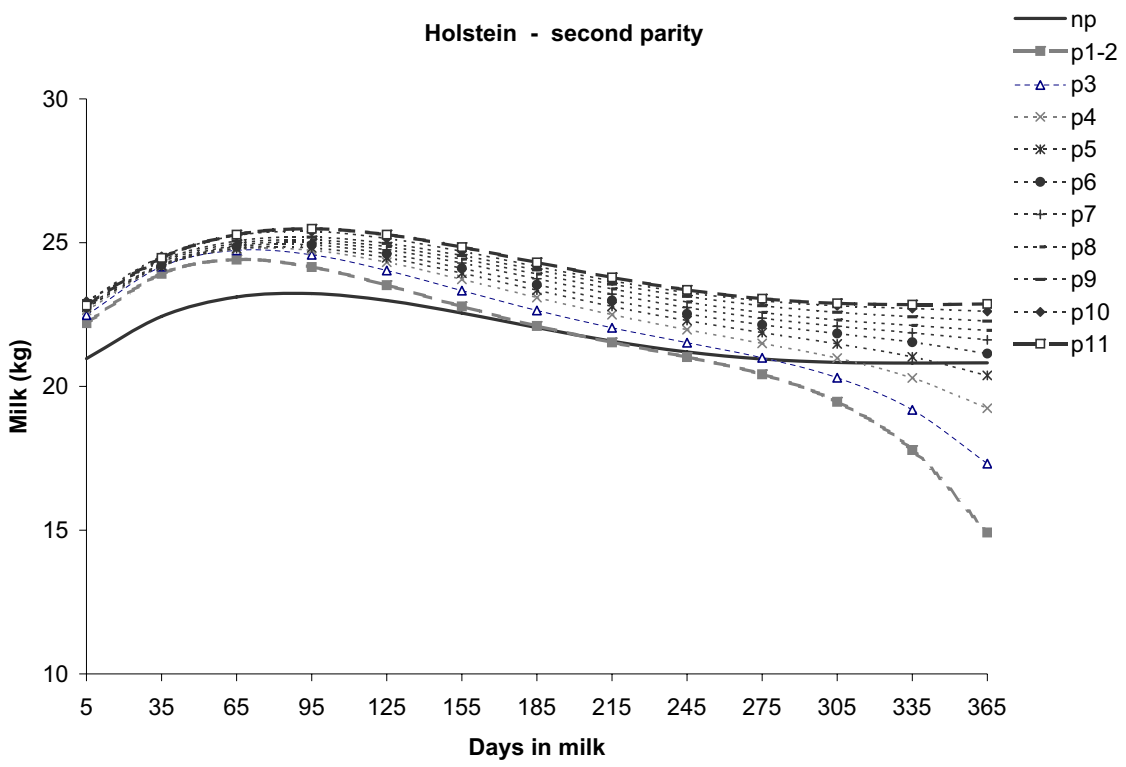

Canadienne - second parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

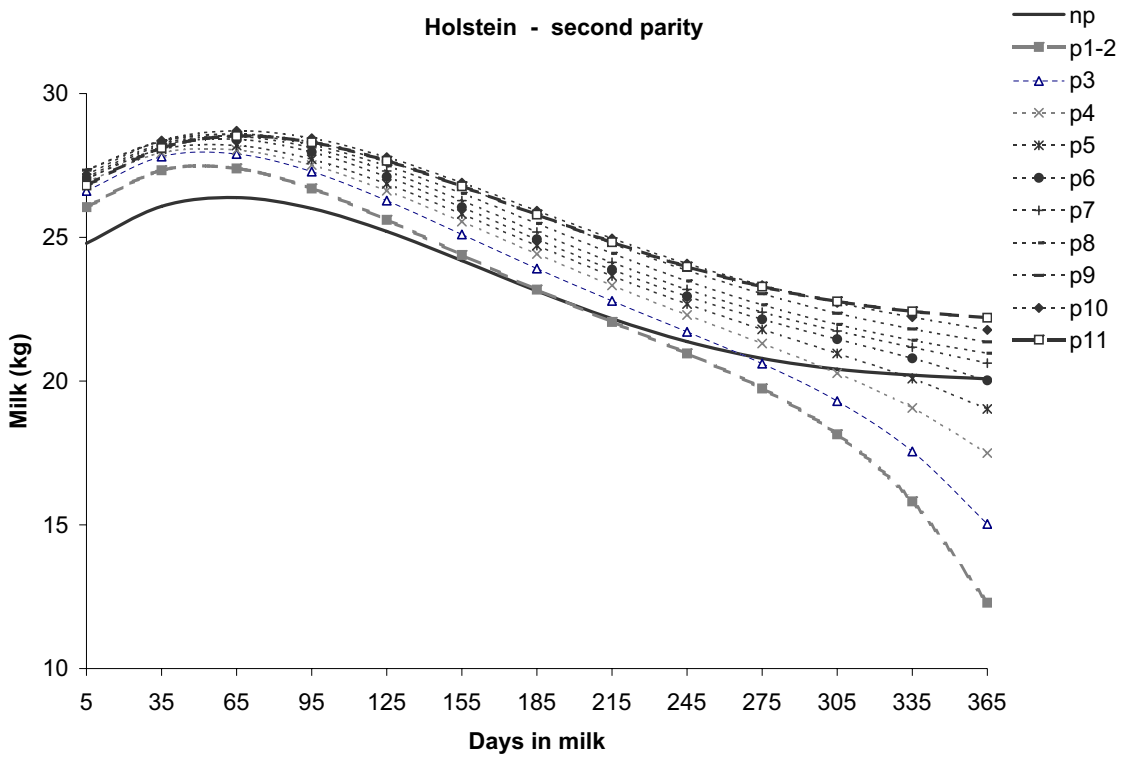

Canadienne - third parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

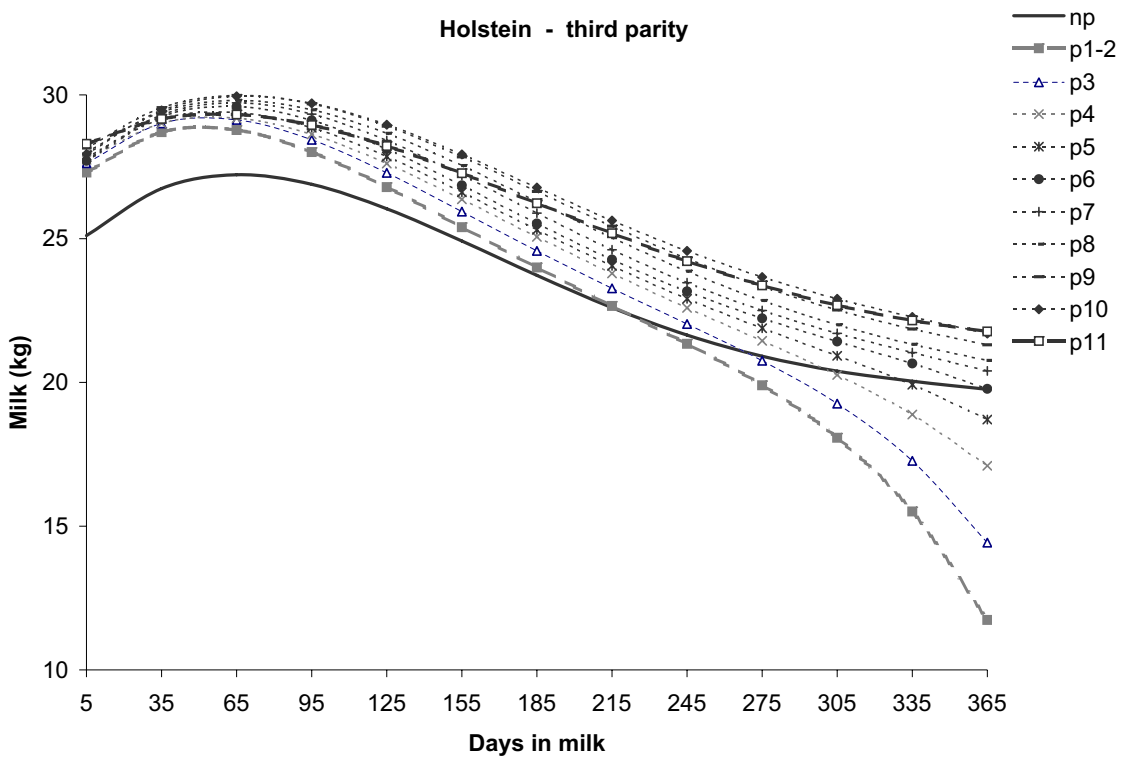

Guernsey - first parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

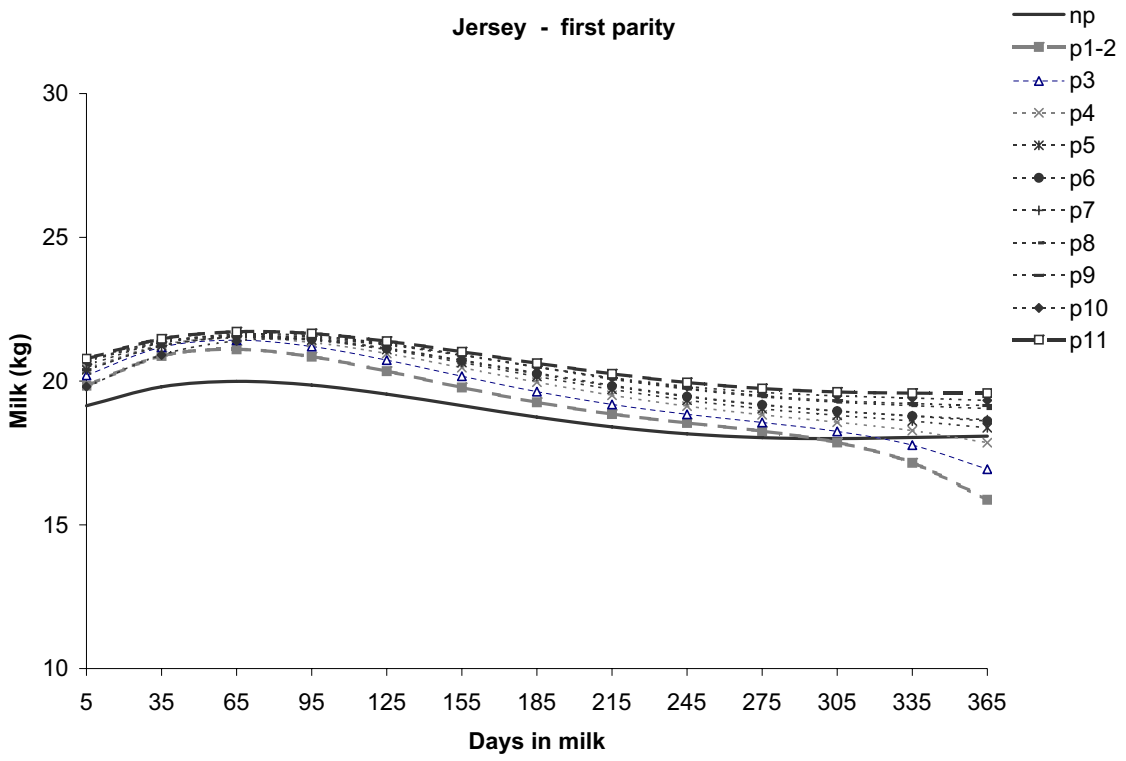

Guernsey - second parity
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11
Milk (kg)
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
Days in milk

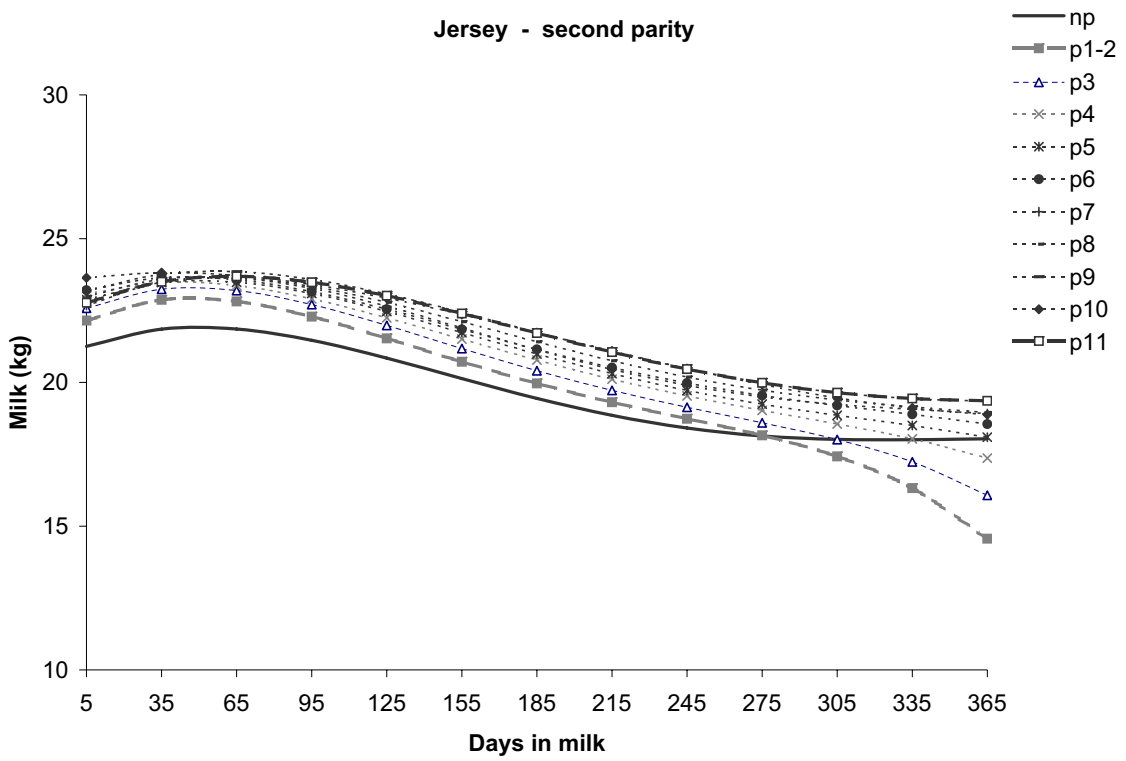

Guernsey - third parity
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11
Milk (kg)
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
Days in milk

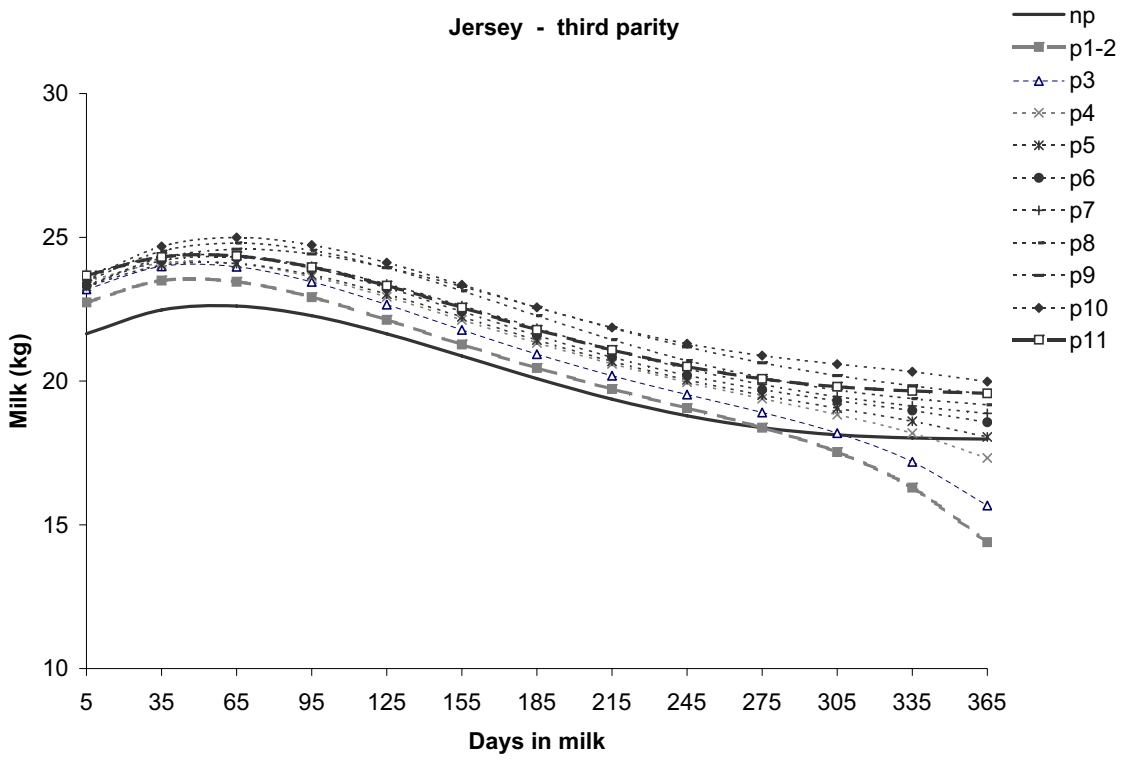

Holstein - second parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

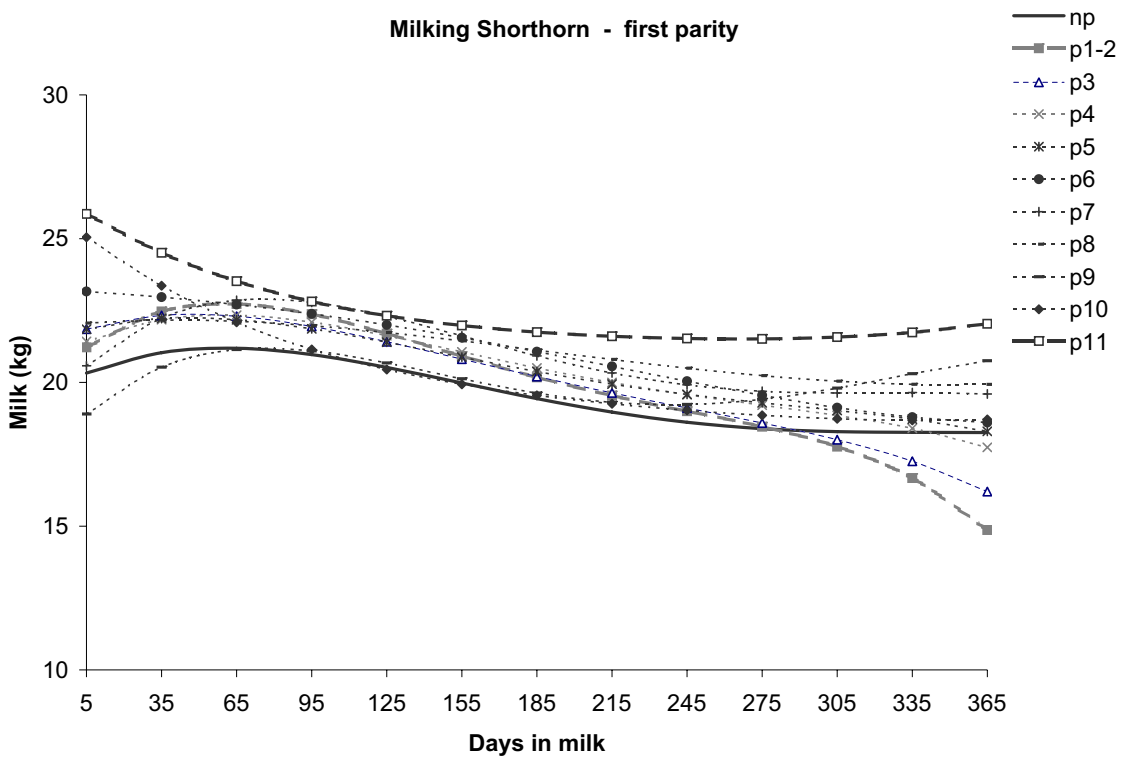

Holstein - second parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

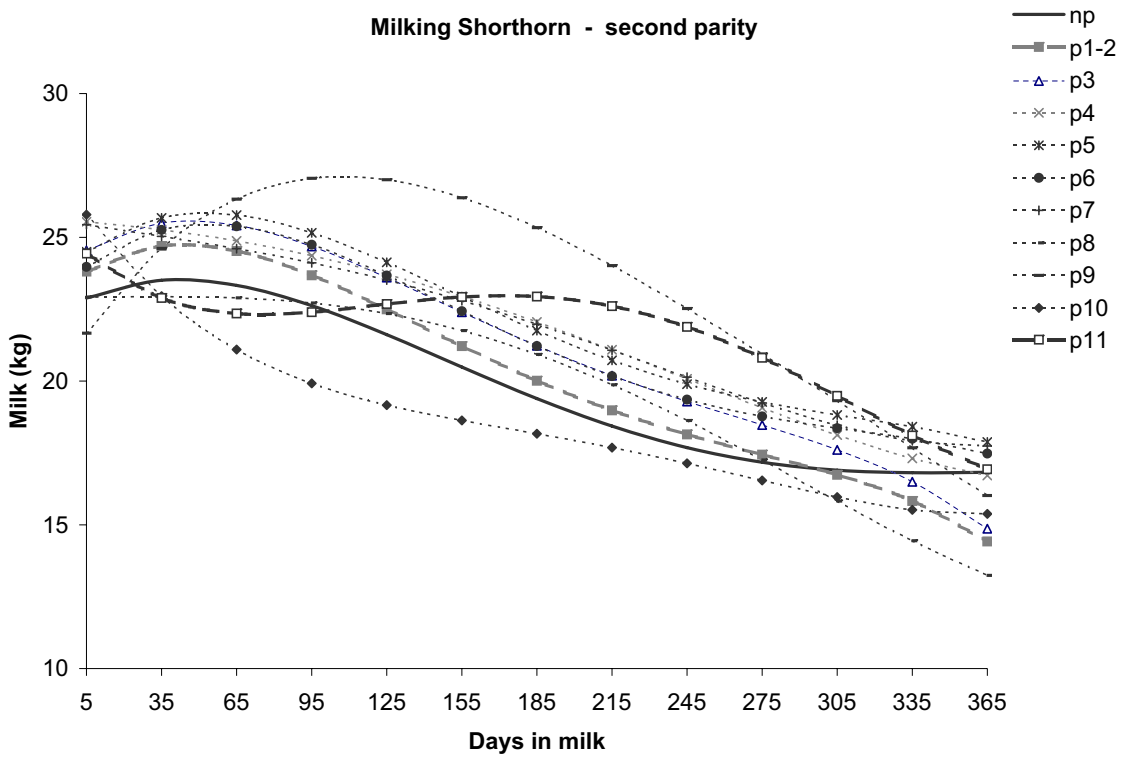

Holstein - third parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

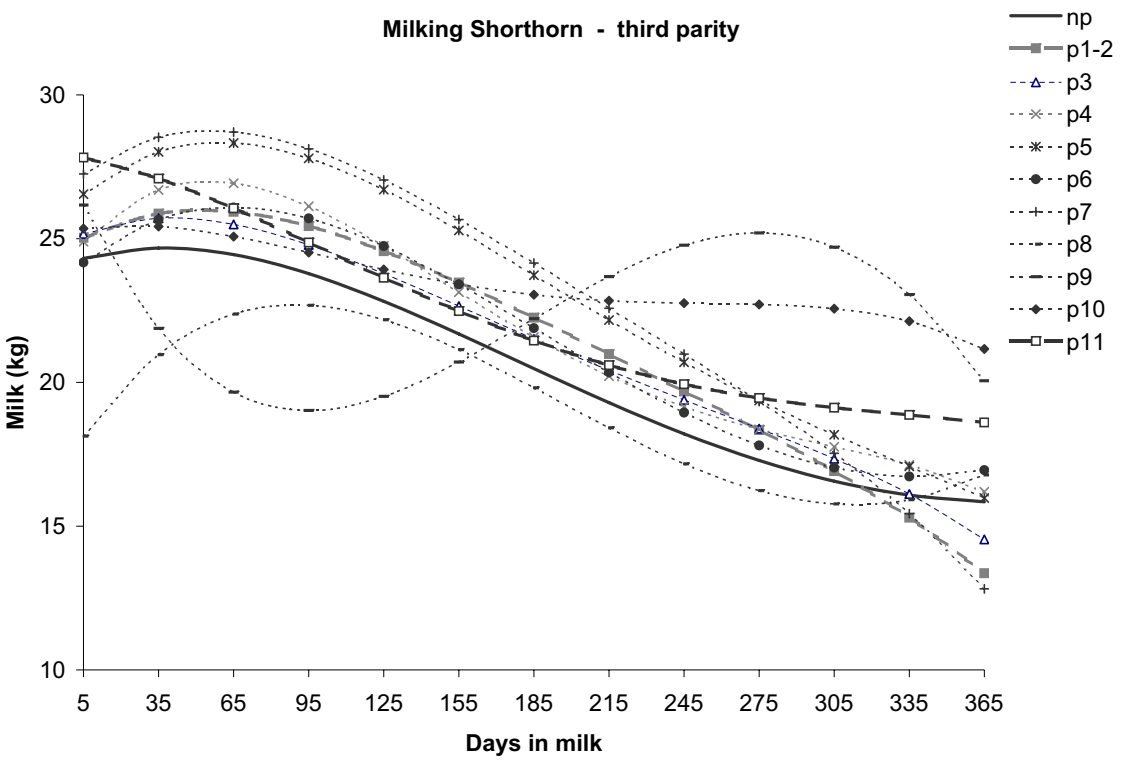

Jersey - first parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

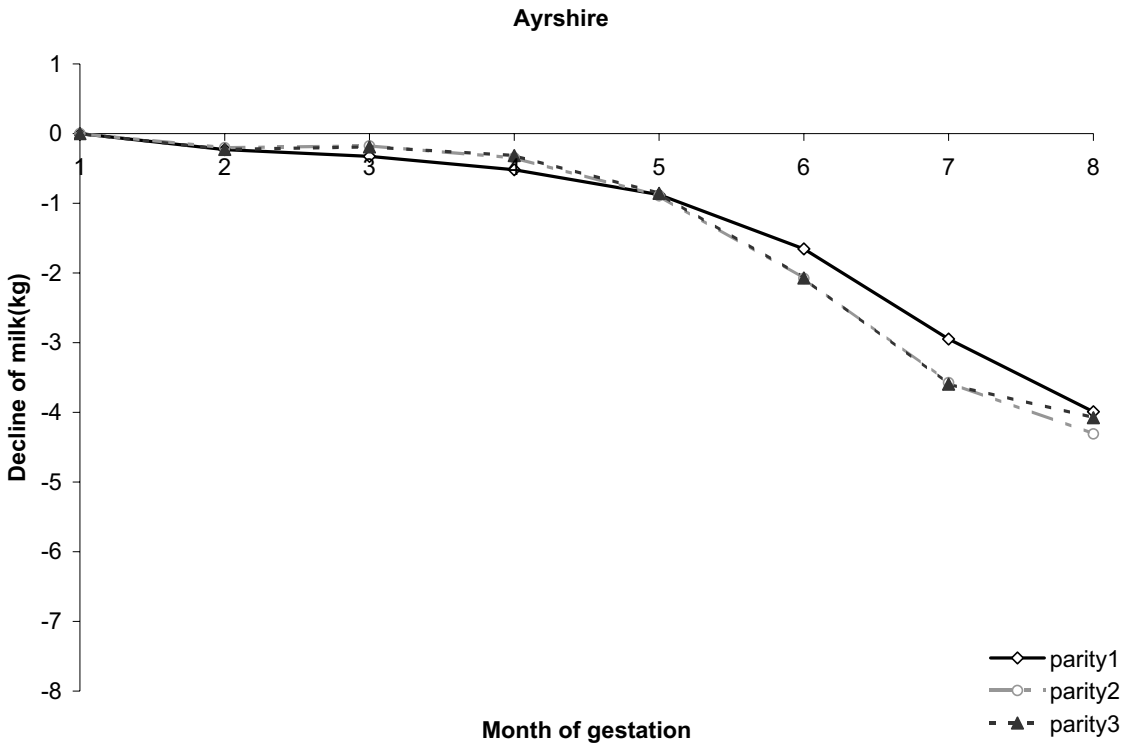

Jersey - second parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

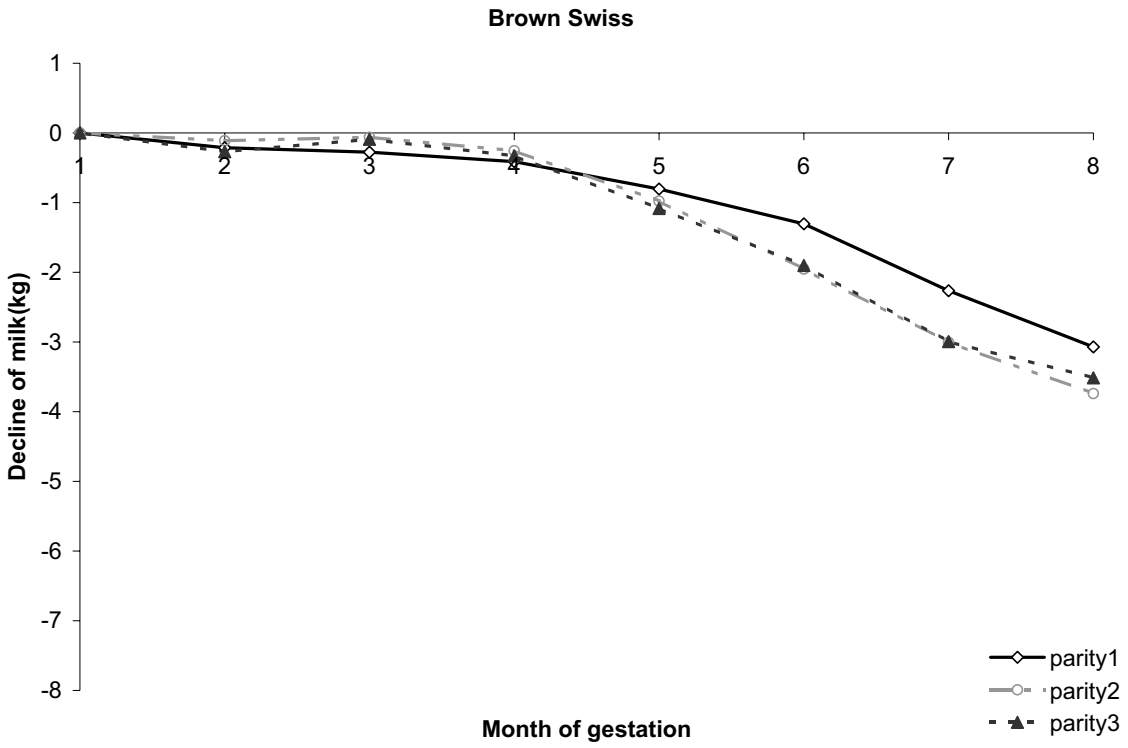

Jersey - third parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

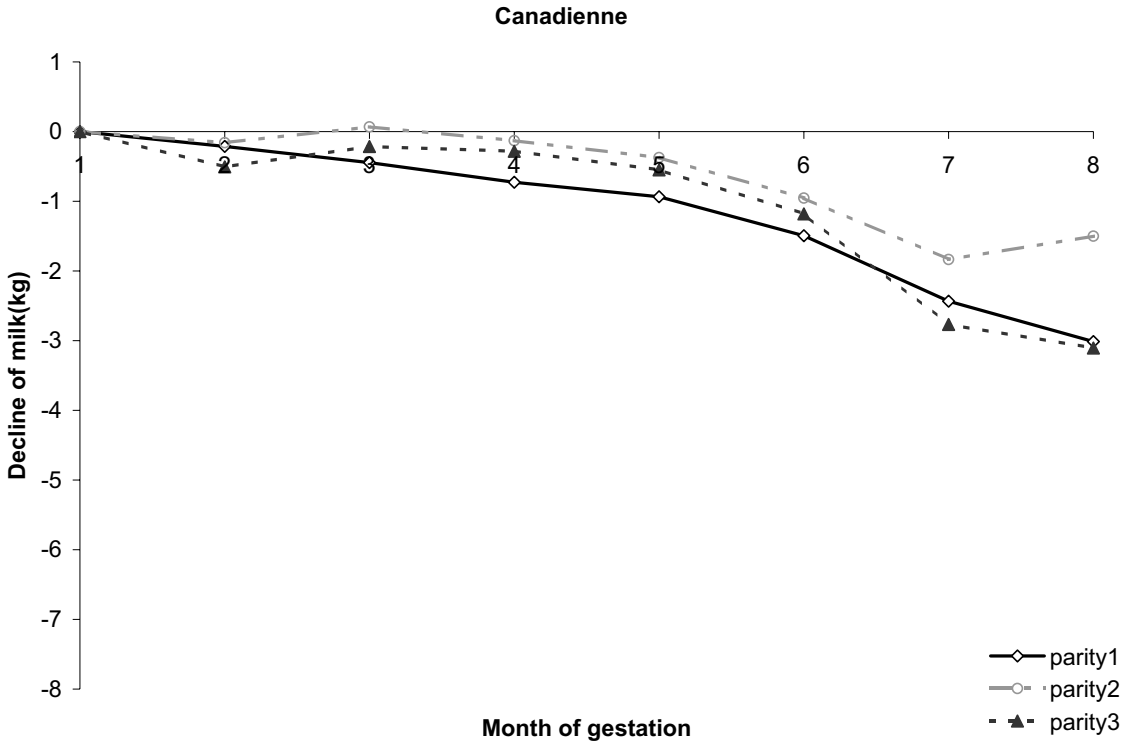

Milking Shorthorn - first parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

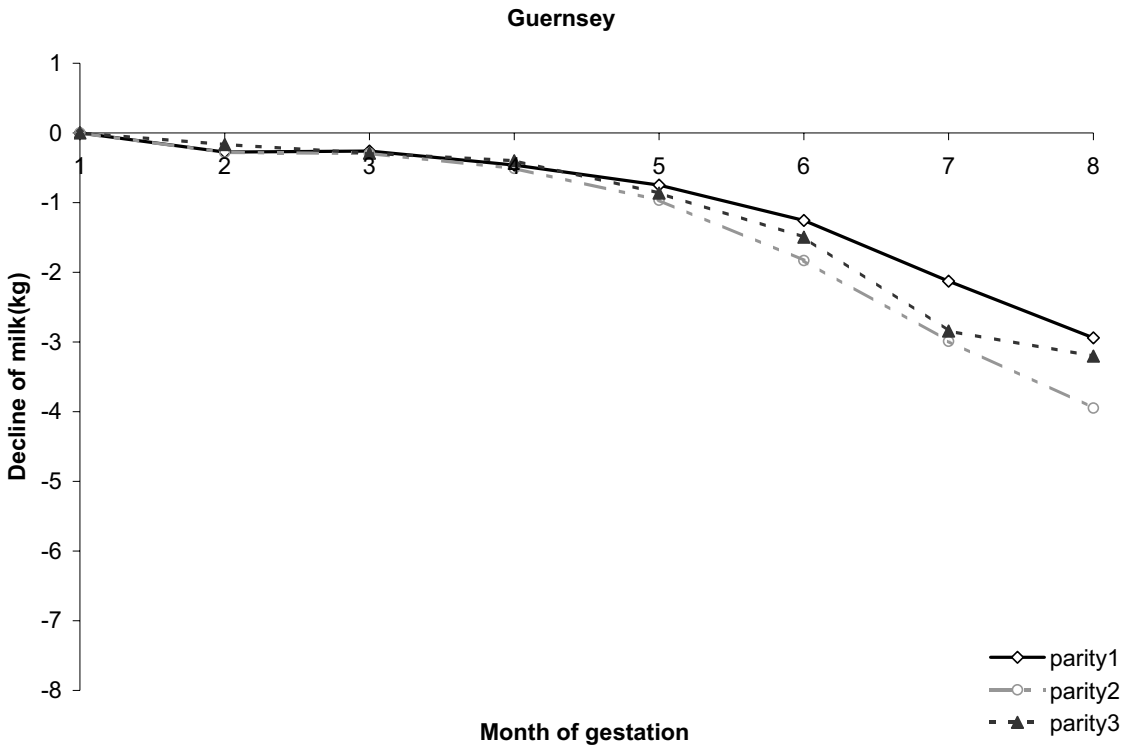

Milking Shorthorn - second parity
Milk (kg)
Days in milk
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11

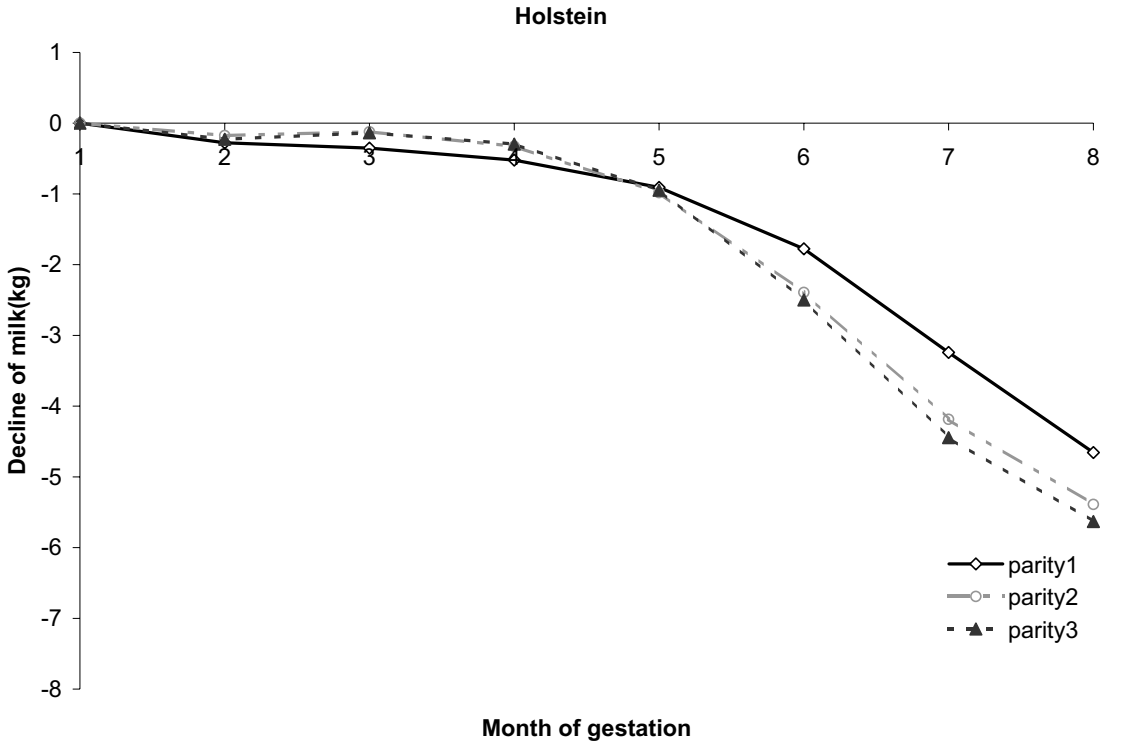

Milking Shorthorn - third parity
np
p1-2
p3
p4
p5
p6
p7
p8
p9
p10
p11
Milk (kg)
30
25
20
15
10
5
35
65
95
125
155
185
215
245
275
305
335
365
Days in milk

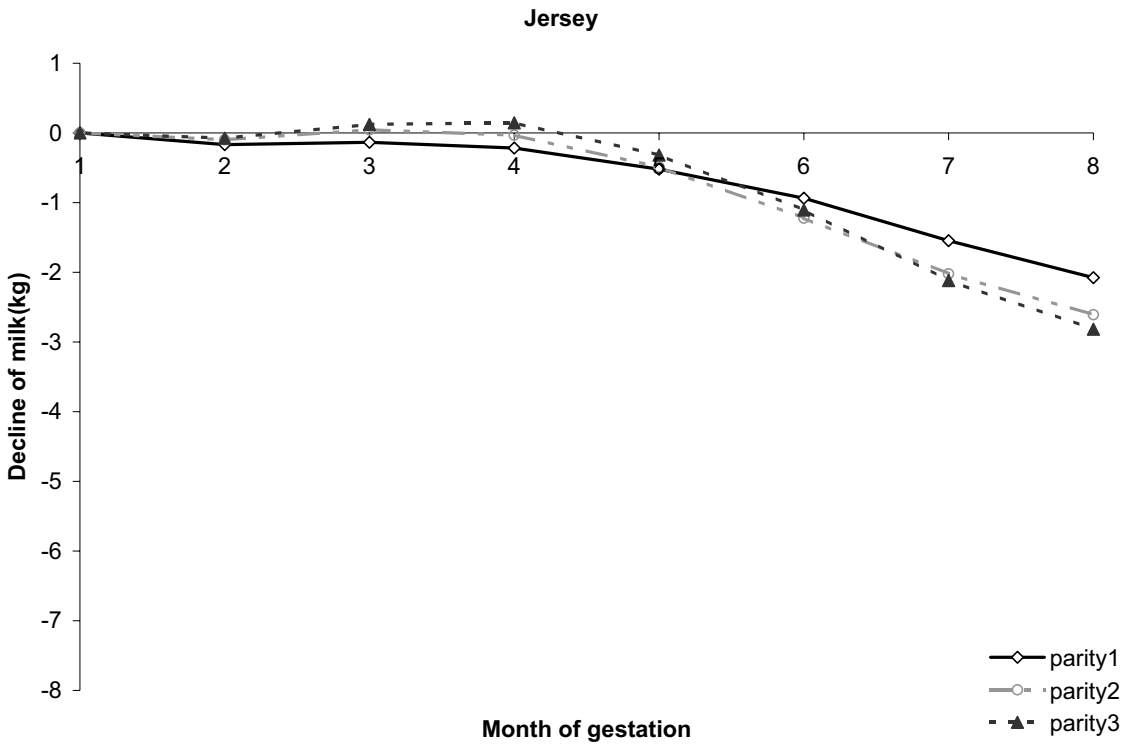

Ayrshire
Decline of milk(kg)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
1
2
3
4
5
6
7
8
Month of gestation
parity1
parity2
parity3

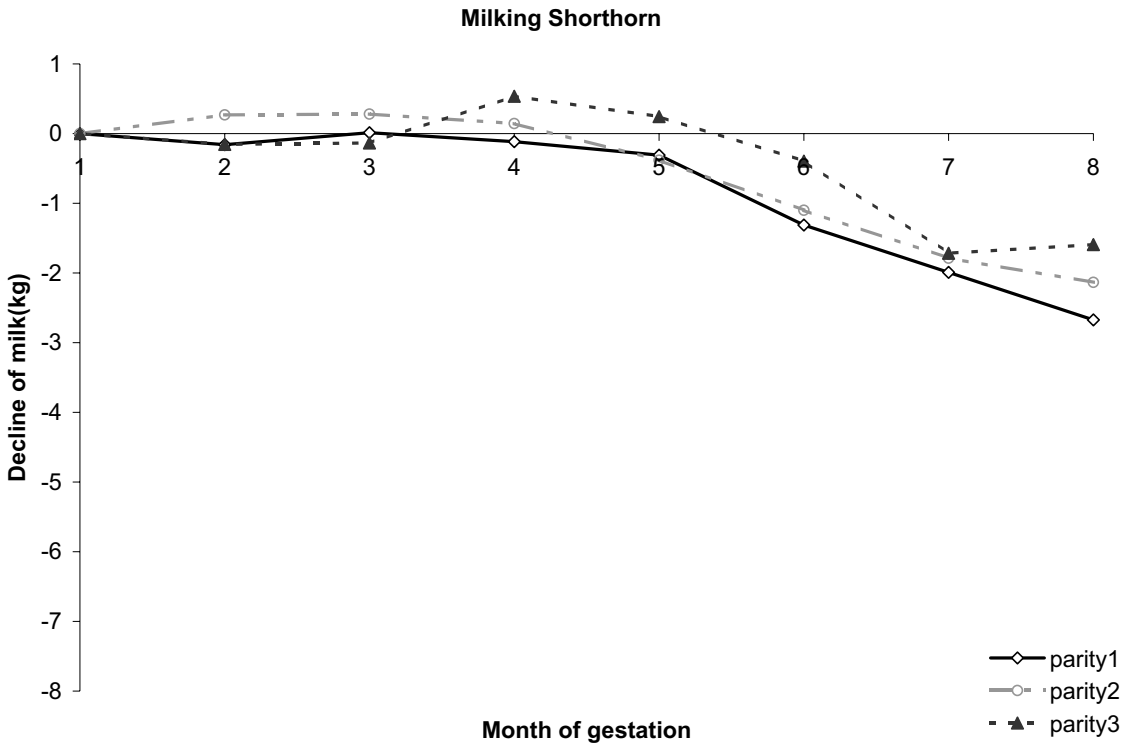

Brown Swiss
Decline of milk(kg)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
1
2
3
4
5
6
7
8
Month of gestation
parity1
parity2
parity3


Canadienne
Decline of milk(kg)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
1
2
3
4
5
6
7
8
Month of gestation
parity1
parity2
parity3


Guernsey
1
0
-1
-2
-3
-4
-5
-6
-7
-8
1
2
3
5
6
7
8
Decline of milk(kg)
Month of gestation
parity1
parity2
parity3


Holstein
1
0
-1
-2
-3
-4
-5
-6
-7
-8
1
2
3
5
6
7
8
Decline of milk(kg)
Month of gestation
parity1
parity2
parity3


Jersey
Decline of milk(kg)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
1
2
3
4
5
6
7
8
Month of gestation
parity1
parity2
parity3


Milking Shorthorn
Decline of milk(kg)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
1
2
3
4
5
6
7
8
Month of gestation
parity1
parity2
parity3