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How does a beef × dairy calving affect the dairy cow's following lactation?

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ABSTRACT

For beef semen usage on dairy cows, much of the research has focused on the performance of the crossbred calves, yet little focus has been given to the subsequent performance of the cow herself. This study aimed to evaluate the performance of dairy cows for milk yield, fertility, and survival traits after giving birth to beef × dairy crossbred calves and compare this with the performance after giving birth to purebred dairy calves. Further, we aimed to study if the effect of a difficult calving was the same regardless of whether the calf was purebred dairy or beef × dairy crossbred. Phenotypic records from 587,288 calving events from 1997 to 2020 were collected from the Swedish milk recording system from cows of the dairy breeds Swedish Red (SR) and Swedish Holstein. The sire beef breeds studied were Aberdeen Angus, Hereford (combined in category LHT), Charolais, Limousin, and Simmental (category HVY). Sixteen traits were defined and grouped in 3 categories: cumulative and 305-d milk, fat, and protein yield, daily milk yield, and 75-d milk yield as yield traits; calving to first insemination interval, calving to last insemination interval, first to last insemination interval, calving interval, and number of inseminations as fertility traits; and survival to 75 d or to next calving and lactation length as measures of survival. The data were analyzed for all traits for first and second parities separately using mixed linear models, with a focus on the estimates of cow breed by service sire breed combinations. All traits in parity 2 were adjusted for previous 305-d milk yield based on the expectation that low-yielding cows would more likely to be inseminated with beef semen. Overall, milk yield was lower after beef × dairy calvings compared with the purebred dairy calvings. The largest effects were found on cumulative yields and in second parity, with lower effects for yields early in lactation and yields in first parity. The largest decrease was 13 to 14 kg (0.12 phenotypic SD) for cumulative fat yield when breeding beef breed sires with purebred SR dams. For fertility traits, for most breed combinations, the effects were not large enough to be significant. Conversely, all beef × dairy crossbred combinations showed significantly lower results for survival to the next lactation, and mostly also for lactation length. There was some indication that dairy cows with beef × dairy calvings in parity 2 that were the result of maximum 2 inseminations in parity 1, had lower survival than corresponding calvings resulting from more than 2 inseminations. This could indicate that the former cows were marked for culling already when inseminated. There was generally an unfavorable effect of a difficult calving on all traits, however, there were almost no significant interactions between calving performance and dam by sire breed combination, and these interactions were never significant in first parity.

Key words: milk yields, fertility, survival, calving difficulty

INTRODUCTION

The use of beef semen on dairy cows is increasing in popularity in many countries (Sørensen et al., 2008; Berry and Ring, 2020a; Berry, 2021). The use of beef sires facilitates the production of beef × dairy crossbred calves in dairy cow herds, providing a potential increase in the economic incomes of the farms because these crossbred calves could be sold for slaughter at a higher price (Ettema et al., 2017; Bittante et al., 2020). Moreover, the use of sexed dairy bull semen to produce female replacement dairy heifer calves enables the utilization of more beef semen in the herd. About 50% of the beef produced in Sweden comes from culled dairy cows and their offspring (Swedish Meat, 2017).

On the negative side, higher calving difficulties for beef × dairy crossbred calvings have been reported also in Sweden, possibly due to the calves' heavier birth weight and better carcass conformation (Eriksson et al., 2020). The effect of difficult calving on the subsequent performance of dairy cows (i.e., milk yield and fertility) has been well demonstrated previously (Coleman et al.,

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1985; Dematawena and Berger, 1997; Berry et al., 2019). Calving difficulty has been associated with a decrease in daily milk production (Barrier and Haskell, 2011; Eaglen et al., 2011) and a decrease in the reproductive efficiency of the herd contributing to a lower number of animals apt to reenter service (Dematawena and Berger, 1997). Eaglen et al. (2011) showed a loss of 710 kg in cumulative milk yield (**MY**) from 129 to 261 DIM after veterinary-assisted calving. Moreover, calving difficulty has negative effects on the subsequent survival of the cows (Lombard et al., 2007; Tenhagen et al., 2007) and their offspring. Therefore, calving traits are associated with milk, fertility, and survival traits.

This knowledge notwithstanding, detailed studies about the effects of beef × dairy calvings, in comparison with purebred dairy calvings, on the cow's following lactation period are still scarce (Berry and Ring, 2020a), and this information would be useful for farmers to understand the total effect of using beef semen on dairy cows. In this study, a large data set of routine performance recording from Swedish dairy producers was used to quantify the effect on the cow's lactation period after giving birth to a purebred dairy or a beef × dairy crossbred calf. The main aim of this research was to evaluate the performance of dairy cows for milk yield, fertility, and survival after giving birth to beef × dairy crossbred calves and compare this to the performance after giving birth to purebred dairy calves. Further, we aimed to study if the effect of a difficult calving was the same regardless of whether the calf was purebred dairy or crossbred beef × dairy.

MATERIALS AND METHODS

Data were obtained from the Swedish milk recording system provided by Växa (www.vxa.se). Ethical approval was not necessary given that the study was done entirely based on already recorded field data. Records involved calving events, insemination information, and milk production from first and second parities. Calving records included unique animal identifications (of the calf, dam, and sire), calving date (birth date of calf), calving ease scores, calf sex, calving herd, and breed (of the calf, dam, and sire). Insemination records contained cow and service sire id, and date of insemination. Cow production records included milk recording date; parity number; calving date; date of birth of cow; test-day (**TD**) milk, protein, and fat yields; and DIM for the TD. Only calvings of purebred Swedish Red (**SR**) and Swedish Holstein (**SH**) cows were used and calvings sired by either SR or SH bulls or beef breed bulls from the most common breeds: Aberdeen Angus (**AAN**), Charolais (**CHA**), Hereford (**HER**), Limousin (**LIM**), and Simmental (**SIM**) breeds. Beef breeds were categorized as sire breeds that include AA and HER (**LHT**) or sire breeds that include CHA, LIM, and SIM (**HVY**).

Definition of Traits

Cumulative milk, fat (**FY**), and protein (**PY**) yields over the whole lactation, along with 305-d milk, fat, and protein yields (**MY305**, **FY305**, **PY305**), were created based on TD milk yield. The yield was assumed to be the same from halfway from the previous TD to halfway to the next TD. For the first TD, the yield was calculated back until d 3 after calving. Similarly, 15 d were added after the last TD. The 305-d yield was defined as the sum of yield (milk, fat, or protein) from d 3 to 307 (inclusive) using the same approach as above. For cows that had shorter lactations than 305 d, the 305-d yields were not calculated. To study effects also on early yield, MY up to d 75 (**MY75**) was calculated similarly to 305-d yield. Daily MY was calculated as cumulative yield over the whole lactation divided by the total number of days the yield was based on.

The 5 fertility traits studied were: interval from calving to first insemination (**CFI**), excluding observations with <20 or >230 d; interval from calving to last insemination (**CLI**), with limits set from 20 to 450 d; interval from first to last insemination, defined as the difference between CLI and CFI, with limits set from 0 to 365 d; number of inseminations per service (**NINS**), with a limit set to 8 inseminations; and calving interval for those cows who had a subsequent lactation, with limits set from 280 to 650 d. Observations with values outside the limits were set to missing.

Survival to subsequent lactation (**SURVNEXT**) was constructed as a binary trait, defined as 1 for the cows that had a subsequent calving, and 0 for those that did not. Survival to 75 d (**SURV75**) was defined as 1 for the cows that had a TD at or after d 75, and 0 for those that did not. Additionally, lactation length (**LACTLEN**), measured as the last TD up to 365 d, was also considered as an indicator of SURVNEXT.

Data Structure and Editing

The original data consisted of a total of 4,980,886 calving events. The data were split into 2 groups: parity 1 and parity 2. Calving age was grouped into month classes nested within parities, with limits for parity 1 set from 22 mo to 34 mo and for parity 2 from 34 to 50 mo. Calving ages outside the limits were combined with the lowest or oldest class within parities (e.g., a first-parity cow aged 35 mo was considered 34 mo old).

Calving records were distributed from January 1997 to September 2020. Data were edited similarly to Eriksson et al. (2020) where herd-year groups (**HYG**) of 4-yr pe-

Table 1. Distribution of calving events per parity

Category	Record (n)	Purebred dairy, n (%)	Dairy × dairy, n (%)	Beef × dairy, n (%)
Parity 1	198,444	161,935 (81.6)	6,599 (3.3)	29,910 (15.1)
Parity 2	388,844	338,480 (87.0)	11,193 (2.9)	39,171 (10.1)

riods (i.e., 1997–2000, 2001–2004, …, 2017–2020) were created and only HYG with at least 5 crossbred calvings from beef breed sires and at least 10 calving events in total were retained, to focus on herds that regularly used insemination with beef semen. The calving records for parity 1 (parity 2) were distributed in 1,404 (2,979) herds, and 2,114 (5,389) HYG were created. Calving ease scores were classified as easy (original scores 1 [old scoring system], 11, or 12 [new system]) or difficult (original scores 2 or 3 [old system], or 13 or 14 [new system]), or missing (all other scores or missing score). Moreover, calving records with abortion (<215 d) and premature calving (215–240 d) were removed from the data set (<5%). The distributions of records per parity and various types of calvings are shown in Table 1. After all edits, a total of 587,288 calving events were used for further analysis (full data).

The numbers of crossbred calvings for the studied beef breeds are shown in Table 2. The main difference in the distribution of calvings with beef sire breeds between parities was the overall increase in the use of heavy breeds, especially CHA and SIM, in parity 2 compared with parity 1. It was decided that there were too few calvings, especially for CHA and SIM in first parity, to study the effect of each breed separately; thus we only used the categories LHT and HVY for further analysis.

Statistical Analysis

The full data set was analyzed independently for each trait with parity 1 and parity 2 separately. Both dam dairy breeds were analyzed simultaneously because it improves the adjustment for the herd-year(-group) effects, considering that those breeds are very often kept in the same farms. Model 1 was as follows:

$$y_{ijklmnopq} = \mu + D{\times}S_{ij} + P_k + S_l + CA_m + CD_n + YS_o + HYG_p + hy_q + b_r\text{MY305dev} + e_{ijklmnopq}, \quad [1]$$

where $y_{ijklmnopq}$ = observed value of the cow (for yield and fertility trait); μ = population mean; $D{\times}S_{ij}$ = fixed effect of breed combination of the calf (dam breed i [SR or SH] by sire breed or breed group j [SR, SH, HVY, or LHT]); P_k = fixed effect of parity k (1 or 2); S_l = fixed effect of calf sex l (male, female); CA_m = fixed effect of age at calving m, grouped into monthly classes as described above, nested within parity; CD_n = fixed effect of calving performance n (easy, difficult, missing); YS_o = fixed effect of year-season o (seasons: Dec. to Feb., Mar. to May, Jun. to Aug., and Sep. to Nov.); HYG_p = fixed effect of herd-year-group combination p (e.g., 1997–2000); hy_q = random effect of herd and calving year combination q, $\sim\text{IND}\left(0, \sigma^2_{hy}\right)$; b_r = fixed regression coefficient of the trait on previous 305-d milk yield as a deviation from the HYG average of first-lactation 305-d yield for second-parity cows (**MY305dev**); for those records lacking previous MY305 information (i.e., cows with shorter previous lactation length than 305 d) the deviation was set to 0 to have them included in the analysis, but without adjusting the next lactation performance; $e_{ijklmnopq}$ = random residual effect, $\sim\text{IND}\left(0, \sigma^2_e\right)$.

Table 2. Distribution of calvings according to cow and sire breed combinations in first and later parities

		Parity 1		Parity 2	
Category[1]	Sire breed[2]	SR	SH	SR	SH
LHT	AAN	3,955	5,622	2,191	2,585
	HER	7,242	5,898	4,376	3,399
HVY	CHA	336	599	3,895	5,417
	LIM	1,566	2,015	2,821	3,041
	SIM	928	1,749	4,272	7,174
	SR	53,185	2,602	118,156	3,363
	SH	3,997	108,750	7,830	220,324
Total		71,209	127,235	143,541	245,303

[1]LHT = sire breeds that include Aberdeen Angus and Hereford; HVY = sire breeds that include Charolais, Limousin, and Simmental.

[2]AAN = Aberdeen Angus; HER = Hereford; CHA = Charolais; LIM = Limousin; SIM = Simmental; SR = Swedish Red; SH = Swedish Holstein.

For the 3 measures of survival (SURVNEXT, SURV75, and LACTLEN), the same model was used but with the MY305dev divided into 3 classes (below −1 SD, between −1 SD and +1 SD, and above +1 SD, all calculated within herd-year-group).

Two additional variables were studied, previous gestation length and previous dry period length (**DPL**, for parity 2) to determine whether they were affected by the breed combination of the calf and whether they in turn influenced MY, as an example trait. In the latter case, we included DPL in 8 classes (<40, 40–49, …, ≥100 d) and gestation length as a linear regression in model 1.

The 305-d milk yield deviation of the previous lactation was included in the model, to account for the expectation that the decision to use beef semen is most likely not independent of the perceived quality of the female. In addition to relatively low milk yield compared with contemporaries, there likely are other reasons to use beef semen on a cow. Therefore, we categorized cows whether they had 1 to 2 or 3 or more inseminations during the heifer period or in parity 1. The assumption was that beef × dairy crossbred calvings resulting from only a few inseminations were intentional from the start, whereas a beef insemination after several failed inseminations was more likely to be a last try to get the cow in calf. Thus, the hypothesis was that some of the cows with beef × dairy crossbred calves as a result of 1 to 2 inseminations were already marked for culling and thus that this group would have a lower SURVNEXT than cow with beef × dairy crossbred calves resulting from more inseminations. Thus, model 2 was created, which is the same as model 1, but additionally included an interaction between dam by sire breed combination and the insemination category.

A third model was created, model 3, where an interaction between the calving performance CD_n and the dam breed by sire breed group combination $D{\times}S_{ij}$ were added to model 1 to test whether calving difficulty had the same effect over all types of calvings (i.e., breed combinations).

R statistical software (R Core Team, 2020) was used to edit the data and compute descriptive statistics. The SAS (SAS Institute, 2012) PROC HPMIXED was used to analyze the linear mixed models, get least squares means and significance of contrasts between all the breed combinations. For some of the studied traits the residuals were not close to be normally distributed (e.g., for survival). However, in our (and other researchers') experience contrasts and significance tests from linear models with (very) large data are robust to any deviation from normality. Some authors even go as far as recommending using linear models for the analysis of 0/1 traits, mostly owing to the direct interpretability of the estimates (Hellevik, 2009; Gomila, 2021).

Table 3. Means and phenotypic SD[1] (σ_p) for all traits

Trait[2]	Parity 1 Mean	Parity 1 σ_p	Parity 2 Mean	Parity 2 σ_p
MY	8,508	2,541	9,769	2,758
MY305	8,979	1,261	10,569	1,328
FY	351	104	401	116
FY305	367	50	431	57
PY	293	87	336	96
PY305	308	40	362	43
DMY	28.3	4.5	32.8	4.8
MY75	2,194	360	2,868	428
CFI	82	31	81	30
CLI	121	65	122	62
FLI	35	53	38	52
CINT	391	55	392	53
NINS	1.96	1.27	2.03	1.28
LACTLEN	283	71	279	72
SURVNEXT	0.65	0.45	0.57	0.37
SURV75	0.96	0.19	0.97	0.17

[1]Calculated as the square root of the sum of the herd-year and residual variances.

[2]MY, FY, PY = cumulative milk, fat, or protein yield over the whole lactation; MY305, FY305, PY305 = 305-d milk, fat, or protein yield; DMY = daily milk yield over the whole lactation; MY75 = total milk yield until d 75 after calving; CFI = interval between calving and first insemination; CLI = interval between calving and last insemination; FLI = interval between first and last insemination; CINT = calving interval; NINS = number of inseminations per service; LACTLEN = lactation length; SURVNEXT = survival to next lactation; SURV75 = survival to 75 d after calving.

RESULTS AND DISCUSSION

All traits, except CFI, LACTLEN, and SURVNEXT, showed a higher mean value in parity 2 than in parity 1 (Table 3). The phenotypic standard deviations (SD) of the traits were, with some exceptions, greater in parity 2 than in parity 1.

Effect of Cow Breed by Service Sire Breed Combinations (Full Data Set)

Overall, the general tendency was that yields were lower after beef × dairy calvings compared with after purebred dairy calvings (Figure 1). The largest effects were found on cumulative yields and in later parities, with lower effects for earlier yields and yields in first parity. For instance, the MY for a SR × LHT calving was ~250 kg lower than a corresponding pure SR × SR calving in parity 2 ($P < 0.0001$), whereas the 305- and 75-d milk yields were only ~21 and 11 kg lower (both $P > 0.05$), respectively. These values correspond roughly to 0.093, 0.016, and 0.027 phenotypic SD, respectively. The largest effect on yield traits was for FY in parity 2 for SR × LHT calving with 13.7 kg ($P < 0.0001$), which corresponded to 0.12 of a phenotypic SD. There was a tendency that yield losses were larger for dairy × beef

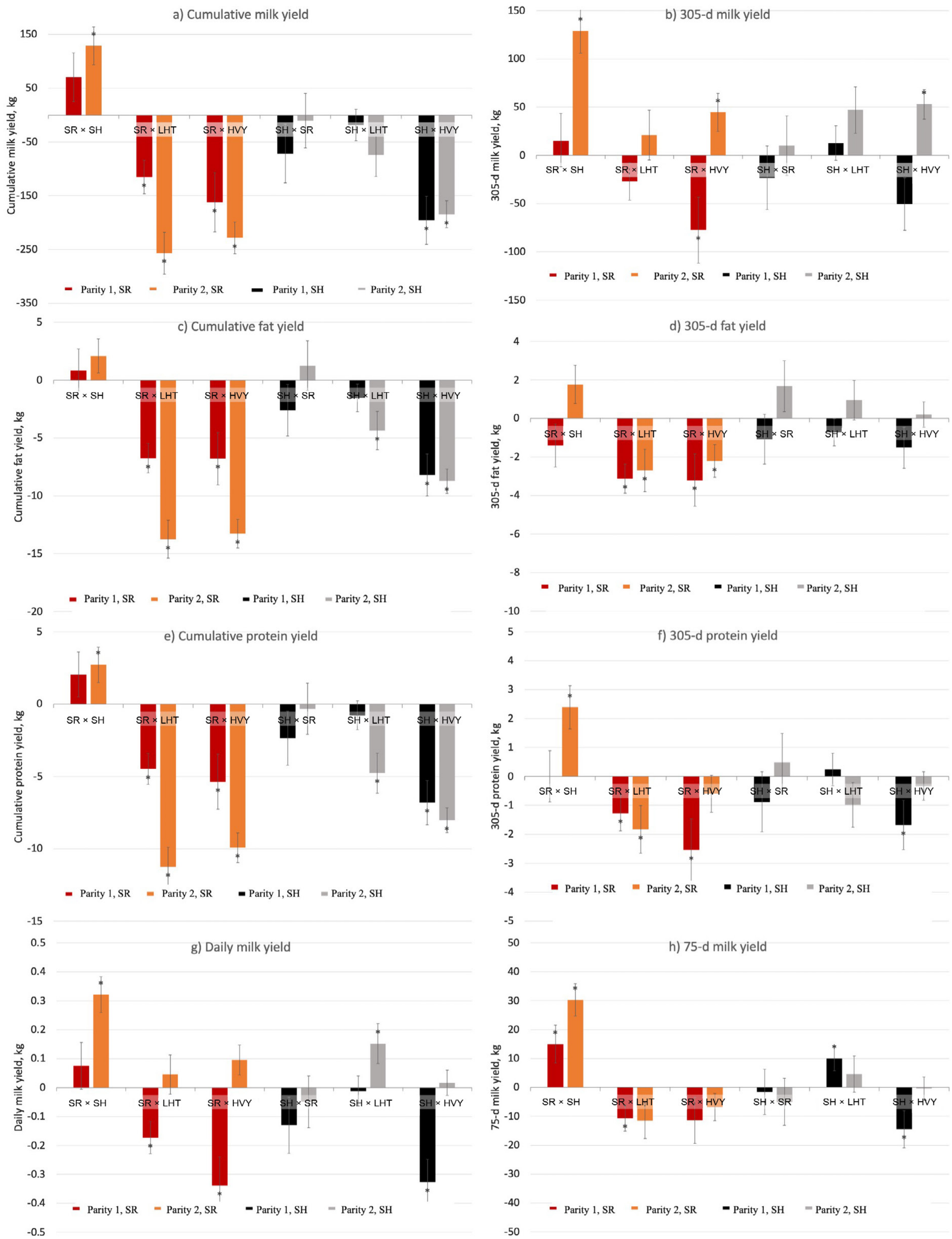

Figure 1. Effect of dam by sire combination on various yield traits in parity 1 or parity 2 for Swedish Red (SR) or Swedish Holstein (SH) dams: (a) cumulative milk yield and (b) 305-d milk yield, (c) cumulative fat yield and (d) 305-d fat yield, (e) cumulative protein yield and (f) 305-d protein yield, and (g) daily milk yield and (h) 75-d milk yield. All crossbred calvings are expressed relative to the corresponding purebred dairy calving (either SR × SR or SH × SH). LHT = sire breeds that include Aberdeen Angus and Hereford; HVY = sire breeds that include Charolais, Limousin, and Simmental. *Significant difference, $P < 0.05$. Error bars show SE. The range of the y-axis corresponds to ~0.2 phenotypic SD.

calvings in SR than in SH, and sometimes even a small yield gain was observed in SH beef crosses (e.g., in SH × HVY for 305-d yield).

Lower yields for beef × dairy calvings were in accordance with a previous report from Ireland. Berry and Ring (2020a) reported a decrease in MY305 of 45.2, 36.7, 101.1, 51.5, and 43.3 kg for AAN, HER, CHA, LIM, and SIM-sired calvings, respectively, compared with a pure dairy Holstein-Friesian calving.

For fertility traits, the deviations of crossbred calvings from purebred dairy calving were generally small and mostly not significant (Figure 2a–e). Of the significant effects ($P < 0.05$), some were favorable, some were unfavorable. Mostly, even significant estimates were close to zero, below ± 2 d for the interval traits ($P < 0.05$) and less than 0.05 for number of inseminations ($P < 0.05$).

All matings with a beef breed sire showed significantly lower survival to next lactation (SURVNEXT, $P < 0.0001$), and most also had shorter lactation length (LACTLEN, $P < 0.001$; Figure 2f, 2g, and 2h). There was a decrease in survival probability of ~0.05 to 0.06 in parity 1 and 0.07 to 0.10 in second parity. Also, early survival (to 75 d) was sometimes significantly lower, by ~0.007 and 0.01, respectively ($P < 0.05$).

There are several possible reasons for the lower yields after beef × dairy calvings compared with after purebred dairy calvings. Females inseminated with beef semen may be those with a low yield in the previous lactation, thus having an expected lower than average yield regardless of the breed composition of the calf. Berry and Ring (2020b) showed such an association between milk yield in the previous lactation and the likelihood of a dairy cow being mated to a beef or dairy sire in Holstein cows in Ireland. The MY305dev in the current study is shown in Figure 3a. Indeed, the 305-d yield for cows later giving birth to beef × dairy crossbred calves was significantly lower than for cows giving birth to a purebred dairy calf by ~190 to 275 kg ($P < 0.05$). However, because we included MY305dev in the model, this should avoid an effect on the estimated effects for the beef × dairy crossbred calvings.

The lower survival to next lactation and shorter LACTLEN could be one of the explanations for the lower MY for the beef × dairy calvings. However, this is not necessarily a causative link. Some of the females inseminated with beef semen may have already been "marked" for culling after having had the next lactation, thus the lower survival for these is expected and is not an effect of the crossbred calving per se. Having said that, we included 3 classes of previous MY305dev in the model, to take account of this preferential treatment. It has been shown previously that low yield constitutes a higher risk of the farmer deciding to cull the cow (within the same lactation), whereas high yield is not "protective" in the same way (e.g., Strandberg and Roxström, 2000; Rostellato et al., 2021). We found that the lowest yield class had a lower survival to next lactation of 4.5 to 5.5 percentage points compared with the other 2 classes, highlighting the importance of adjusting survival for previous milk yield in a nonlinear manner.

One possible physiological reason for the lower milk yield after having had a beef × dairy crossbred calf, as also suggested by Berry and Ring (2020a), is that the larger energy need for a larger and faster-growing calf could have a spillover effect on the next lactation. We did not have any information to test this hypothesis in our data. A related explanation could be if the gestation length is different depending on the breed combination of the calf. We found that gestation length in heifers carrying a crossbred LHT beef × dairy calf was shorter than that for heifers bearing a purebred dairy calf, by ~8 to 15 d, with the largest effect found in SR dams (Figure 3b). The gestation length was also substantially reduced for an SR heifer carrying a crossbred SR × SH calf (−10 d). However, the effect of a shorter gestation length was very small, ~0.9 kg for MY. Atashi and Asaadi (2019) found a decrease in 305-d milk yield of almost 190 kg in first-parity cows when the previous gestation length decreased by 9 d from the average length.

During first parity (i.e., cows here denoted as second parity) there was a slight prolongation of gestation length for beef × dairy crossbred calvings, by up to 5 d ($P < 0.05$; Figure 3b). Basiel et al. (2023) found that beef sire breeds resulted in longer gestation length by 1 to 7 d, depending on breed, compared with a purebred Holstein calving, for cows at second or later calving. In our data, an increased gestation length in first parity increased MY in second parity by ~6 kg/d. Atashi and Asaadi (2019) found that an increase from the average gestation length by 1 d increased 305-d milk yield by ~11 kg. When adjusting for previous gestation length in the model for MY, there was mostly a positive effect on the differences in relation to the purebred dairy calvings (Figure 3c and 3d). This meant that the negative effects were somewhat ameliorated, except for the crossbred SR × SH, where the previous positive effect became smaller. There was a similar effect of this adjustment on early milk yield (MY75) as for MY (Figure 3e and 3f). Thus, it seems that a small part of the negative effect generally found for beef × dairy crossbred calvings can be explained by variation in gestation length. There was also a slightly higher incidence of twin calvings for SR × HVY and SH × HVY versus purebred SR or SH (3.1%–3.2% vs. 2.0%–2.5%) that might have had a small effect.

Another factor that could influence the next lactation yield is the DPL. We found that DPL was 10 to 19 d longer preceding a calving with a beef × dairy calf (Figure 3g). Both too-short and too-long DPL have been shown to

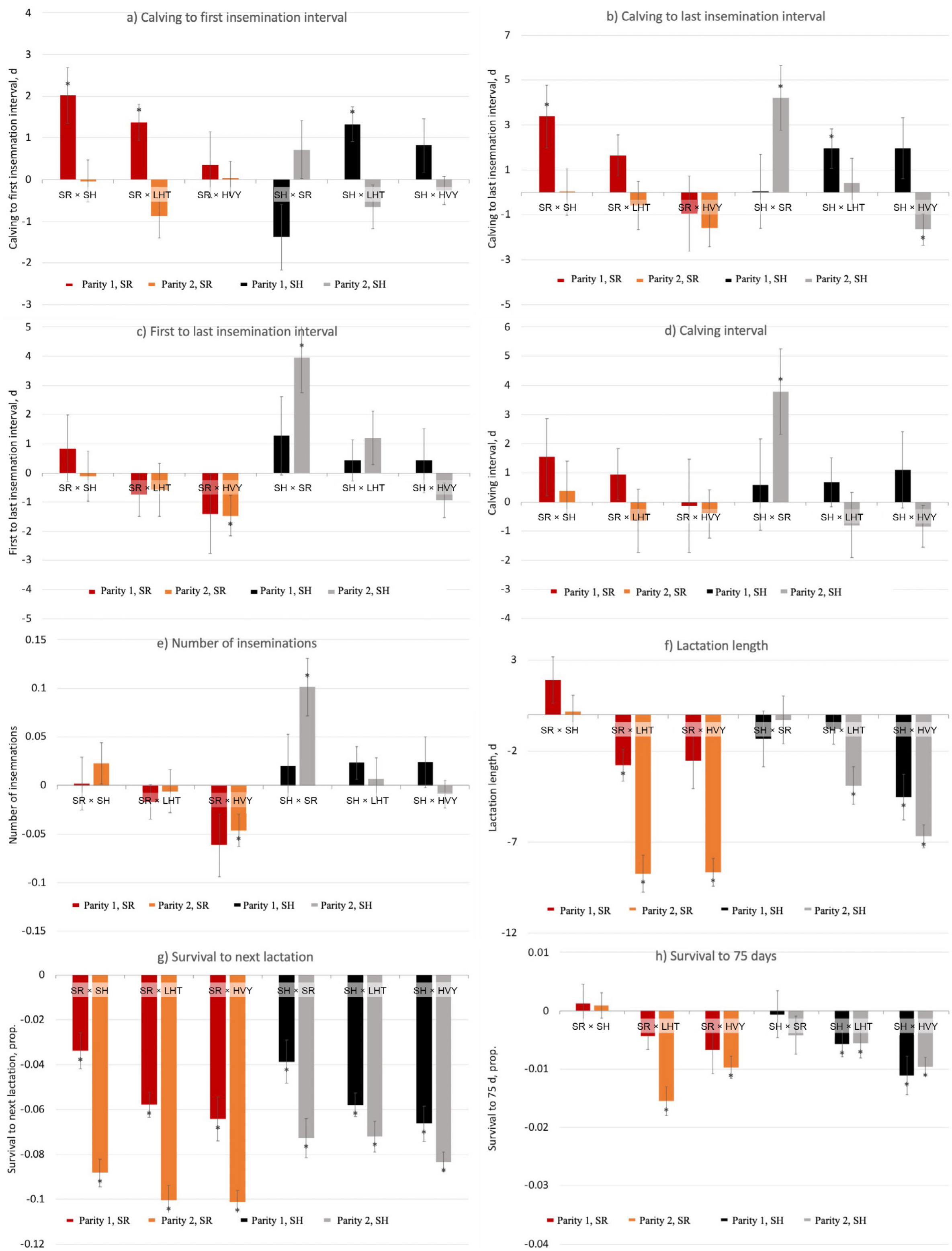

Figure 2. Effect of dam by sire combination on various fertility and survival traits in parity 1 or parity 2 for Swedish Red (SR) or Swedish Holstein (SH) dams: (a) calving to first insemination, (b) calving to last insemination, (c) first to last insemination, (d) calving interval, (e) number of inseminations, (f) lactation length, (g) survival to next lactation as a proportion (prop.), (h) survival to 75 d as a proportion (prop.). All crossbred calvings are expressed relative to the corresponding purebred dairy calving (either SR × SR or SH × SH). LHT = sire breeds that include Aberdeen Angus and Hereford; HVY = sire breeds that include Charolais, Limousin, and Simmental. *Significant difference, $P < 0.05$. Error bars show SE. The range of the y-axis corresponds to ~0.2 phenotypic SD.

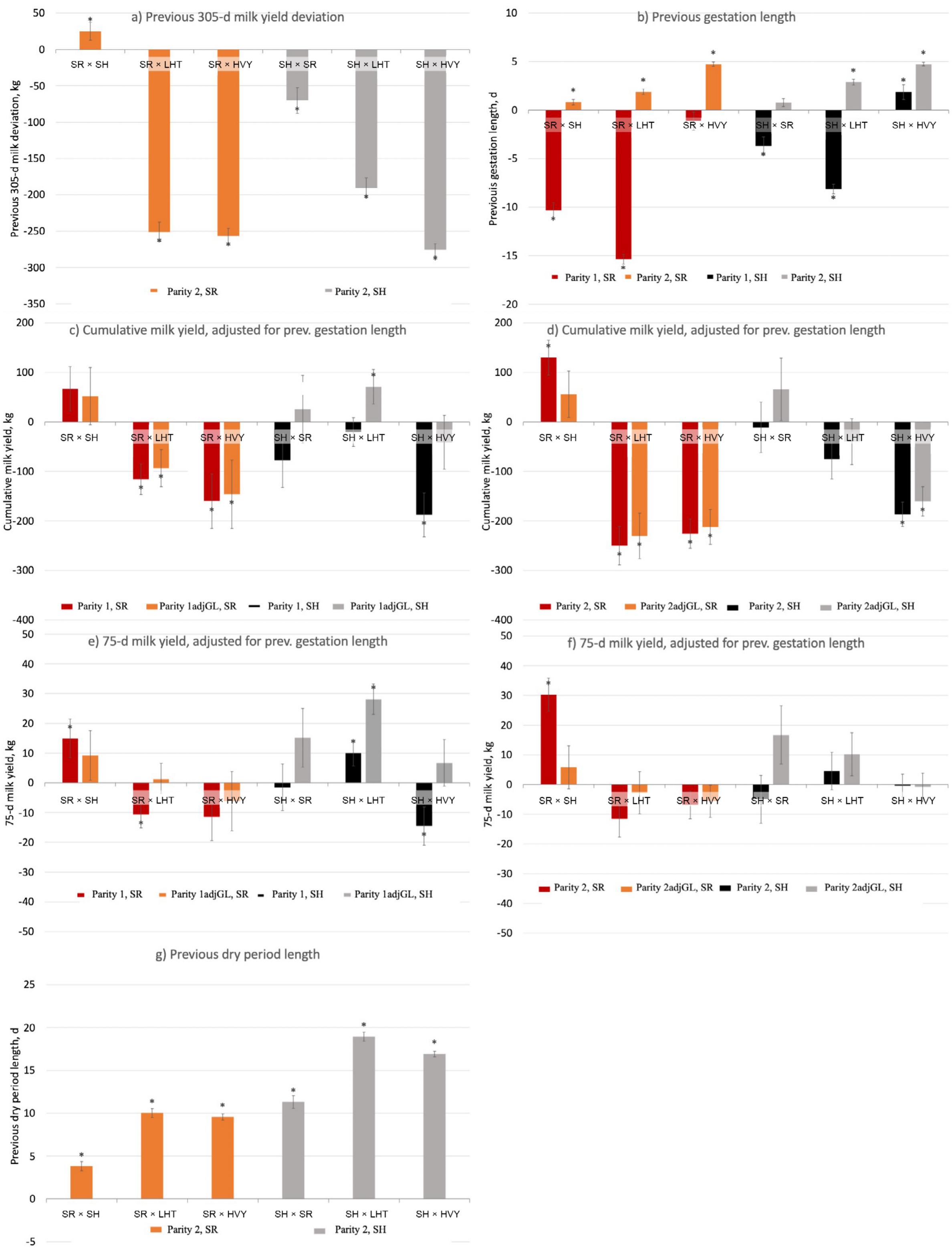

Figure 3. Association between dam by sire combination of the calf for Swedish Red (SR) or Swedish Holstein (SH) dams and (a) previous 305-d milk yield as a deviation from the corresponding herd-year-group average, (b) previous gestation length, (c) cumulative milk yield in parity 1 with or without adjustment for previous gestation length (adjGL), (d) cumulative milk yield in parity 2 with or without adjGL, (e) 75-d milk yield in parity 1 with or without adjGL, (f) 75-d milk yield in parity 2 with or without adjGL, (g) previous dry period length. All crossbred calvings are expressed relative to the corresponding purebred dairy calving (either SR × SR or SH × SH). LHT = sire breeds that include Aberdeen Angus and Hereford; HVY = sire breeds that include Charolais, Limousin, and Simmental. *Significant difference, $P < 0.05$. Error bars show SE.

be detrimental for the following milk yield (e.g., Andrée O'Hara et al., 2020). We found that DPL shorter than 40 d was associated with ~500-kg lower MY, compared with DPL of 40 to 79 d, whereas longer DPL decreased yield with 90 to 150 kg (results not shown). However, when we adjusted for DPL in the model for MY, the effect on the differences between breed combinations was very small (less than 7 kg, not shown).

Guilbault et al. (1990) found that prepartum decrease in progesterone concentrations and increase in estrone concentrations were faster in Ayrshire heifers bearing Limousin fetuses than in those bearing Ayrshire fetuses. Also, the concentrations of prostaglandin $F_{2\alpha}$ were lower during the postpartum period in Ayrshire heifers that gave birth to Limousin calves than in those that had Ayrshire calves. Thus, also in our data there may be endocrinological changes in the dam owing to the beef × dairy crossbred fetus that affect the milk yield in the coming lactation.

Effect of Number of Inseminations in Previous Lactation (Parity 1 and Parity 2 Data Sets)

The hypothesis was that beef × dairy calvings that were the result of 1 to 2 inseminations in the previous lactation were intentional, and that some of these cows were marked for culling already when inseminating them. Therefore, a lower survival would be expected in this category than in the category with more inseminations. The decrease in SURVNEXT for a crossbred calving was very pronounced for parity 2, more so than for parity 1 (Figure 2g).

Survival to next lactation (calving) was numerically lower for beef × dairy calvings in parity 2 with 1 to 2 inseminations than for corresponding calvings with more inseminations in the previous lactation, however, this difference was only significant for SR × HVY (Table 4). The lower survival for cows in the category with 1 to 2 inseminations may have contributed to the large decrease in survival for crossbred beef calvings in parity 2 shown in Figure 2g for the full data set, especially because 55% to 75% of all calvings belonged to this insemination category. However, it is not the sole explanation, because there was a decrease in survival also for SR × SH, but the survival tended to be higher for NINS 1 to 2 than for NINS >2 (Table 4).

When comparing the SURVNEXT in parity 1 for categories with NINS 1 to 2 or NINS >2 during the heifer period (Table 4), there were only small differences in survival between the 2 categories, none being significant (P-values > 0.05), and sometimes with lower survival for the category with >2 inseminations. This could indicate that fewer females were marked for culling and for that reason inseminated with beef semen as virgin heifers.

This lower survival will lead to a shorter LACTLEN (Figure 2f), which in turn would be expected to lead to a lower cumulative yield (Figure 1a, 1c, and 1e). Therefore, for effects of beef × dairy crossbred calvings on yield per se, it would be better to study early or 305-d yields, which are (more) unaffected by culling.

Effect of Calving Difficulty

It is known that beef by dairy calvings often lead to increased calving difficulties compared with purebred dairy calvings (e.g., McGuirk et al., 1998; Fouz et al., 2013). In Swedish data, Eriksson et al. (2020) showed that crossbred calvings from heavy breeds (CHA, LIM, or SIM) gave 4% to 5% higher incidence of difficult calvings in first parity, but only ~2% in later parities. The LHT breeds (AAN or HER) resulted in 1% or less increase in calving difficulties in all parities. In our data, there was ~2.5% higher incidence of calving difficulties in first parity for dairy × beef crossbred calvings for HVY beef sires but at most 0.5% higher incidence for LHT beef breed

Table 4. Comparison of survival to next lactation for first-parity cows with different numbers of inseminations during the heifer period and second-parity cows with different numbers of inseminations during the first parity

	Parity 1[1]			Parity 2		
Dam × sire breed[2]	NINS 1–2	NINS >2	P-value	NINS 1–2	NINS >2	P-value
SR × SR	0.645	0.638	0.26	0.479	0.486	0.46
SR × SH	0.645	0.642	0.90	0.496	0.466	0.39
SR × LHT	0.625	0.605	0.19	0.401	0.402	0.96
SR × HVY	0.615	0.592	0.39	0.393	0.442	0.03
SH × SH	0.663	0.656	0.12	0.484	0.477	0.21
SH × SR	0.675	0.639	0.22	0.412	0.425	0.76
SH × LHT	0.636	0.654	0.17	0.417	0.444	0.22
SH × HVY	0.628	0.628	0.64	0.418	0.444	0.10

[1]NINS = number of inseminations per service; P-value test examines whether the LSM for survival is different for the 2 groups, NINS 1–2 and NINS >2 (P < 0.05 considered significant).

[2]SR = Swedish Red; SH = Swedish Holstein; LHT = sire breeds that include Aberdeen Angus and Hereford; HVY = sire breeds that include Charolais, Limousin, and Simmental.

sires. The effects were smaller than that in second parity (results not shown). However, it is not known whether the consequences of a difficult calving are different when a purebred dairy cow gives birth to a beef × dairy crossbred calf, compared with giving birth to a purebred dairy calf. This was studied by having an interaction effect between calving performance and dam by sire breed combination in model 3. Table 5 shows the main effects (i.e., the effect of a difficult calving minus that for an easy calving). The interaction effect was never significant (P-values > 0.05) in first parity. For second parity, the interaction was significant (P-values < 0.05) only for daily MY and MY75. However, the effect of a difficult calving for a given beef × dairy crossbred calving was only significantly different from the effect of a difficult calving for the corresponding purebred calving for MY75, and then only for SH × LHT. The difference in MY75 between a difficult and an easy calving for SH × LHT was 35 kg, whereas that difference was 118 kg for SH × SH (P < 0.05).

In general, there was a negative effect of a difficult calving on yield traits, and the effect was often larger in parity 2 than in parity 1. Fertility and survival were also unfavorably affected by a difficult calving; however, fertility was generally more severely affected in parity 1. Survival to next generation was decreased by 4 to 9 percentage points and SURV75 by about 1 percentage point. Thus, a higher relative frequency of difficult calvings for beef × dairy calvings could be contributing somewhat to the lower survival and milk yields found in this study.

Table 5. Effect of calving difficulty as a deviation from easy calving, LSM differences for main effects

Trait[1]	Parity 1	Parity 2
MY	−159.6*	−239.8**
MY305	−61.2[ns]	−99.4**
FY	−6.5*	−9.7**
FY305	−2.8[ns]	−1.8**
PY	−5.3*	−8.0**
PY305	−2.3*	−3.1*
DMY	−0.47***	−0.47***
MY75	−46.4***	−57.8***
CFI	3.2**	3.8**
CLI	8.8***	6.7**
FLI	5.8***	3.5[ns]
CINT	9.2***	4.0[ns]
NINS	0.12*	0.11*
LACTLEN	−2.2[ns]	−4.6[ns]
SURVNEXT	−0.04***	−0.09***
SURV75	−0.011*	−0.012*

[1]MY, FY, PY = cumulative milk, fat, or protein yield over the whole lactation; MY305, FY305, PY305 = 305-d milk, fat, or protein yield; DMY = daily milk yield over the whole lactation; MY75 = total milk yield until d 75 after calving; CFI = interval between calving and first insemination; CLI = interval between calving and last insemination; FLI = interval between first and last insemination; CINT = calving interval; NINS = number of inseminations per service; LACTLEN = lactation length; SURVNEXT = survival to next lactation; SURV75 = survival to 75 d after calving.

*P < 0.05; **P < 0.01; ***P < 0.0001; ns = not significant. If the interaction effect was not significant, the values for subclass means are not shown.

Effects on Dairy × Dairy Crossbred Calvings

Although the main aim was not to study the effects of dairy × dairy crossbred calvings, the results are nevertheless interesting. An SR cow giving birth to a SR × SH calf had generally higher yields than a corresponding cow giving birth to a purebred SR calf, and slightly worse fertility in first parity (CFI and CLI; Figure 1 and Figure 2). However, the effect on survival was still negative but slightly smaller than that for beef × dairy crossbred calvings. For the corresponding dairy crossbred calving for SH cows, the difference with purebred SH calving were never significant for yields (Figure 1) but an impaired fertility was found in second parity (P < 0.05; Figure 2). Adjusting for gestation length decreased the positive effect on yield for SR × SH (Figure 3) but the effect for SH × SR was still not significant and adjusting for previous DPL had very small effect also for these crossbred calvings (not shown).

CONCLUSIONS

In general, cows having had a beef × dairy calving had lower milk, fat and protein yields in the following lactation. The lower cumulative yields were partly owing to lower survival rates for these cows, leading to shorter lactation lengths and thus lower cumulative yields, however, also 75- and 305-d yields were generally negatively affected. Cumulative yields were at most decreased by 0.12 phenotypic SD-units, whereas 305-d yields were lowered by at most 0.06 SD-units. Fertility traits were mostly not significantly affected. There was some indication that cows with beef × dairy calvings in parity 2 that were the result of maximum 2 inseminations in parity 1, had lower survival than corresponding calvings resulting from more than 2 inseminations, however, the evidence was weak. There were some effects of previous gestation length and previous DPL, but adjusting for these factors did not fully remove the negative effects on yield, especially not in second parity. There was generally an unfavorable effect of a difficult calving on all traits, however, there were almost no significant interactions between calving performance and dam by sire breed combination, and never in first parity.

NOTES

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Abbreviations used: AAN = Aberdeen Angus; CFI = interval from calving to first insemination; CHA = Charolais; CINT = calving interval; CLI = interval from calving to last insemination; DPL = dry period length; FLI = interval between first and last insemination; FY = fat yield; FY305 = 305-d FY; HER = Hereford; HVY = sire breeds that include CHA, LIM, and SIM; HYG = herd-year groups; LACTLEN = lactation length; LHT = sire breeds that include AA and HER; LIM = Limousin; MY = milk yield; MY75 = total milk yield until d 75 after calving; MY305 = 305-d MY; MY305dev = MY305 as deviation from average; NINS = number of inseminations per service; PY = protein yield; PY305 = 305-d protein yield; SH = Swedish Holstein; SIM = Simmental; SR = Swedish Red; SURV75 = survival to 75 d; SURVNEXT = survival to subsequent lactation; TD = test-day.

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